PHYSIOLOGICAL RESPONSES OF ADULT MALES TO REGULAR EXERCISE

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ABSTRACT

The purpose of this investigation was to determine the comparative effects of training by jogging, circuit weight training, swimming and calisthenics/endurance games on middle-aged men. Sixty-five volunteers, between twenty-seven to forty-eight years of age, were randomly assigned to one of four activity groups: jogging (n=15), circuit weight training (n=18), swimming (n=16) and calisthenics/endurance games (n=16). All groups trained for fifteen to sixty minutes, three to five times per week for sixteen weeks, at sixty to ninety percent maximum heart rate reserve.

At the completion of the programme thirty-five subjects had met the specified requirements; circuit weight training (n=14), swimming (n=11) and calisthenics/endurance games (n=10), representing a retention rate of fifty-three percent. The results of the jogging group were eliminated from statistical analysis due to a very high drop out rate which left an insufficient number (n=2) for satisfactory evaluation.

The circuit weight training, swimming and calisthenics/endurance games groups had an average attendance of 3.5, 4.3 and 3.4 days per week respectively. A significant ($p < 0.05$) difference was observed in average attendance, with the swimming group having a higher average attendance than the other two groups.

Each subject was tested at the commencement of the programme, following eight weeks and again after sixteen weeks of regular physical activity. During this time span, all groups improved significantly ($p < 0.05$) in all work capacity and cardiovascular parameters. This was shown by increased physical work capacity at 170 beats per minute

from 1189 to 1521 $kg.m.min^{-1}$, 1264 to 1584 $kg.m.min^{-1}$ and 1084 to 1381 $kg.m.min^{-1}$; and 14.9 to 18.9 $kg.m.kg^{-1}.min^{-1}$, 15.2 to 19.55 $kg.m.kg^{-1}.min^{-1}$ and 14.47 to 18.6 $kg.m.kg^{-1}.min^{-1}$ for circuit weight training, swimming and calisthenics/endurance games groups respectively. Predicted heart rate at 140 watts decreased significantly ($p < 0.05$) from 144.4 to 123.5 b.p.m., 141.7 to 116.0 b.p.m. and 152.0 to 128.8 b.p.m. respectively. Resting systolic and diastolic blood pressures reduced significantly ($p < 0.05$), from 135.5 to 126.4 mmHg, 143.2 to 133.1 mmHg, 134.6 to 124.4 mmHg and from 82.5 to 72.9 mmHg, 87.4 to 81.1 mmHg, 82.3 to 75.3 mmHg respectively.

Body composition did not change with training, as no significant decrease occurred in skinfold measurements, percent body fat or weight. No significant changes were observed in three spirometry measurements (F.V.C., $F.E.V_{1.0}$, $F.E.V._{1.0\%}$) or in blood lipids (cholesterol and triglycerides). Serum high density lipoprotein reduced significantly in all groups ($p < 0.05$) over the sixteen week programme from 1.08 to 0.84 $mM.L^{-1}$, 1.1 to 0.8 $mM.L^{-1}$ and 1.0 to 0.8 $mM.L^{-1}$ in the circuit weight training, swimming and calisthenics/endurance games groups respectively. High density lipoprotein as a percentage of total cholesterol decreased significantly ($p < 0.05$) in the circuit weight training group, from 23.2 to 18.6 percent.

Dietary analysis during the fourth and twelfth weeks of the programme showed that there were no significant changes in either the total energy intake or the percentage of energy intake derived from fat, during the study.

Changes that occurred with regular physical activity were independent of the mode of activity. It was concluded that while improving the cardiovascular system, exercise alone does not appear to modify body weight and composition or the levels of lipids in the blood. Therefore some other factor in conjunction with exercise seems to be necessary to favourably modify health-related fitness. This factor is most likely to be a decrease in total energy intake and a reduction in the proportion of the energy intake derived from fat.

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THE PROBLEM

INTRODUCTION

Community awareness concerning the health benefits of regular physical activity is increasing in Australia. Since 1974 when a Gallup Poll showed that two-thirds of Australians had not exercised in the prior twelve months, the number of people exercising on a regular basis has increased. Evaluations of the "Life. Be in it" campaign conducted in 1976 and 1977 show that public awareness of that programme had increased from 79 percent in 1976 to 97 percent in 1977. One half of the people surveyed indicated that the programme had made them aware of how to be more active and most of these people had responded by translating this awareness into added regular activity (92) Data collected by the Roy Morgan Research Centre in February 1982 indicated that 27% of Australians now exercise three or more times per week (92).

Through the distribution of information booklets, the National Heart Foundation of Australia has also been responsible for increasing public awareness of the benefits of regular exercise (57, 58, 59). The Foundation states that there is a significant relationship between low cardiorespiratory fitness and a higher risk of the development of premature coronary heart disease (57, 58).

In these and other ways members of the community are becoming more aware that regular exercise is necessary to develop and maintain an optimal level of health, performance and appearance.

In the Ballarat region this increased public awareness has been demonstrated by the increased participation in at least one community activity. In 1980, 140 people participated in the inaugural Courier-Begonia Festival fun run, and in 1981 this same event attracted 355 entrants.

The benefits to be gained from regular exercise are directly related to the intensity, duration and frequency of the programme, and the type of activity selected (103). The authoritative American College of Sports Medicine has published a position statement concerning the recommended quantity and quality of exercise for developing and maintaining fitness in healthy adults. This states:

> "Based on the existing evidence concerning exercise prescription for healthy adults and the need for guidelines, the American College of Sports Medicine makes the following recommendations for the quantity and quality of training for developing and maintaining cardio-respiratory fitness and body composition in the healthy adult:
>
> 1. Frequency of training: 3 to 5 days per week.
> 2. Intensity of training: 60 percent to 90 percent of maximum heart rate reserve of 50 percent to 85 percent of maximum oxygen uptake ($\dot{V}O_2$max).
> 3. Duration of training: 15 to 60 minutes of continuous aerobic activity. Duration is dependent on the intensity of the activity, thus lower intensity activity should be conducted over a longer period of time. Because of the importance of the "total fitness" effect and the fact that it is more readily attained in longer duration programmes, and because of the potential hazards and compliance problems associated with high-intensity activity, lower to moderate intensity activity of longer duration is recommended for the non-athletic adult.
> 4. Mode of activity: Any activity that uses large muscle groups, that can be maintained continuously, and is rhythmical and aerobic in nature, e.g. running-jogging, walking-hiking, swimming, skating, bicycling, rowing, cross-country skiing, rope skipping and various endurance game activities." (2)

STATEMENT OF THE PROBLEM

Within the guidelines of the American College of Sports Medicine (2), the recommended activity patterns may vary in the physiological benefits to be effected from regular exercise or training.

In the Ballarat region jogging is a popular outdoor activity while indoor activities (swimming, health studios, and calithenics programmes) also attract large numbers of participants, especially during the winter months.

This thesis will examine four activity programmes which are popular in the Ballarat region (jogging, swimming, circuit weight training and calisthenics/endurance games), evaluating the benefits of each for previously sedentary healthy adult males exercising within the guidelines of the American College of Sports Medicine.

REVIEW OF RELATED LITERATURE

PHYSIOLOGICAL CHANGES THAT OCCUR WITH AGE

In general terms most performance variables of males increase with age until the mid to late twenties. These peak values are usually maintained until the age of thirty after which there is a gradual decline.

Physical Characteristics:

Evidence indicates that standing height decreases with age due to a secular increase in height of one centimetre per decade and due to changes in the configuration of the vertebral column accentuated by intervertebral disc compression and the development of kyphosis with aging (45, 95).

Body weight increases with age up to 45 years and this change is associated with an increase in body fat. Following the age of 45 body weight tends to stabilise, due not to a decrease in body fat but to a reduction in lean body mass (5, 22, 61, 84, 93).

Cardiorespiratory Measures at Rest:

The major functional changes in the cardiorespiratory system at rest which are observed with advancing age are increased residual volume (5, 6, 18), and blood pressure (103) and diminished cardiac output (4), forced vital capacity (5, 18), and forced expiratory volume in one second (9).

Response to Submaximal Exercise:

While there is no difference between age groups in oxygen uptake at a set submaximal workload (6, 33, 75) the older subjects are likely to be working at a higher percentage of their maximal oxygen uptake (77). This is reflected in elevated pulmonary ventilation (77), due to a higher blood lactate accumulation (33). The submaximal exercise heart rate at a given workload is usually higher in the older person (notably when expressed as a percentage of maximum heart rate (6, 33). This indicates that the older individuals will be working closer to their maximum capacity. During work there is a greater increase in blood pressure in the older individual. These factors may place the older person at greater risk during exercise due to the increased cardiac work and myocardial oxygen demand (87).

Maximum Oxygen Uptake: (Physical Work Capacity)

Maximal oxygen uptake ($M\dot{V}O_2$) reaches a peak value at approximately 25 years of age, followed by a gradual decline during the rest of the life span (5, 64, 103). The anticipated rate of decline is 4 to 5 millilitres of oxygen per kilogram per minute ($ml.kg^{-1}.min^{-1}$) per decade between the ages of 25 and 65 (45). Most of the reduction in $M\dot{V}O_2$ with age is associated with the reduction of the maximum attainable heart rate with age (84, 87) along with other parameters involved in the process of oxygen transport and utilisation.

Strength:

Maximum muscular strength and endurance are developed by the age of 25 years and are usually maintained until the age of 45. Following the age of 45 muscular strength and endurance decrease with age (5, 64, 103). This reduction in strength may be related to the decrease in lean body mass which occurs at the same time. Disuse of muscle through lack of activity will result in atrophy of the muscles and consequently a decrease in strength could be expected with lack of regular exercise (5, 103).

Influence of Physical Training on the Aging Processes:

Individuals who have remained physically active throughout life do not appear to experience the same rate of decline in physiological function as their sedentary counterparts. There is still a decline in performance variables but regular physical activity appears to retard the processes associated with aging (45, 64, 73, 75, 86, 87, 103). The benefits of physical training in retarding the aging process in $M\dot{V}O_2$ are demonstrated by Masters athletes who show a decline of only 2 to 3 $ml.kg^{-1}.min^{-1}$ per decade from the age of 35 years to 65 years (45). Masters swimmers from the age of 27.5 years have an annual decrease in performance of one percent. Some of these swimmers have been able to retard and actually reverse this annual decrement with age by increasing their amount of training (73).

PHYSIOLOGICAL CHANGES THAT OCCUR WITH TRAINING

Improvements in cardio-respiratory fitness and body composition that result from physical training are related to the intensity, duration and frequency of activity. In general terms the magnitude of improvement is dependent upon the total energy cost of the programme. Other factors which influence the nature of the training response are the type, or mode, of exercise, the initial fitness level and age of the subjects.

Intensity, Duration and Frequency of Activity:

Intensity of Activity:

Improvement in aerobic power, measured as $M\dot{V}O_2$, is directly related to the intensity of the physical training programme (1, 21, 23, 90), and this may be the most effective factor in promoting increased work capacity (7, 83).

The minimal threshold level for enhancement of endurance fitness is a work load corresponding to 50 percent $M\dot{V}O_2$ (23). This may be equated with a heart rate of 60 percent maximum heart rate reserve added to the resting heart rate (2, 3), where maximum heart rate reserve is the difference between maximum and resting heart rates. As a linear relationship exists between heart rate and submaximal work intensity (3), the heart rate method of determining training intensity is highly practical and has been significantly correlated to measured oxygen uptake ($\dot{V}O_2$) (24). Also the percent maximum heart rate reserve method corrects for the non-zero value of resting heart rate. The relationship between heart rate and work intensity is independent of age and initial fitness level and therefore this method of determining the minimum training intensity can be used for both middle aged adults and for endurance athletes (24).

Pollock et al (67) measured the effects of high intensity training (80 and 90 percent maximum heart rate reserve) and found that there was no difference in improvements in $M\dot{V}O_2$ and body composition between the two groups. This indicates that beyond a certain intensity no further gains were made in training response. Also with high intensity training there appeared to be a greater risk of injury (46). These are the reasons for the recommended upper intensity of 60 to 90 percent maximum heart rate reserve or 50 to 85 percent $M\dot{V}O_2$ (2).

Swenson and Conlee (91) found that changes in body composition were related not to intensity of physical activity alone, but were influenced by nutritional caloric intake. This indicates the need to monitor or control caloric intake in studies of physical activity. Changes in body composition are generally obtained when an energy expenditure of approximately 1255.8 kilojoules (KJ) per exercise session is attained (2). The total caloric cost of an activity session is dependent upon both the intensity and duration of the exercise session (2,64, 69).

Duration of Activity:

Improvements in cardiorespiratory fitness and body composition parameters are directly related to the duration of the training sessions. Increased aerobic power and decreased skinfold thickness and diastolic blood pressure following training have been found to be proportional to the duration of the exercise session (51, 68).

Intensity and duration of the activity sessions are interdependent and are considered to be the two most important factors determining the nature of the training response (1, 23). This is because the combination of training intensity and duration determines the total energy expenditure of an activity (2, 64). The amount of total work performed during training is the important factor in improvement of fitness and body composition parameters (2, 64, 82, 83). This suggests that activities of lower intensity and longer duration will produce a similar training response to activities of higher intensity and shorter duration.

In general the shorter duration programmes (5 to 15 minutes) of moderate intensity show a significantly lower training effect than those of 30 to 60 minutes duration (3, 23, 51, 68, 69, 83). Improvements in endurance fitness have been obtained with high intensity training sessions of only 5 to 10 minutes duration (51, 83), however these high intensity sessions are not desirable for most sedentary participants due to the greater risk of injury.

Activity sessions must be of a sufficient duration to elicit a training response no matter what the intensity. Improvements in endurance fitness require a minimum or threshold duration of activity of 15 minutes per session (2, 3). With sessions of excessive duration (45 minutes or longer) there is an increased risk of injury to participants (68). Therefore the optimum duration of an activity session to promote endurance fitness and body composition changes is between 15 and 60 minutes (2, 3).

Frequency of Activity:

Shephard (83) and Davies and Knibbs (23) found that frequency of training was of less importance than intensity or duration, in improving $M\dot{V}O_2$. Although of lesser value, improvements in $M\dot{V}O_2$

and body composition had been found to be related to the frequency of training. Frequencies of 3 to 5 times per week produced gains superior to once per week (21, 27, 31, 41, 65, 68), but higher frequencies of training have been found to increase the incidence of injury (68).

Some research has indicated that there is no interaction between the intensity, duration and frequency of training (7, 21, 82); whereas other studies indicate that intensity and duration are interdependent (1, 23) or that the three factors in combination influence the training response (2, 83). It seems most likely that there is a combination of intensity, duration and frequency of activity which will produce the optimum training response. This combination may take into account the minimum and maximum values for each of the training variables, beyond which the training process is ineffective either from the point of insufficient total work output, or the increased incidence of injury respectively.

The American College of Sports Medicine (2) has made recommendations concerning the intensity, duration and frequency of exercise required for the development and maintenance of cardiorespiratory fitness and body composition in the healthy adult. These are:

a) Intensity of training should range from 60 to 90 percent of maximum heart rate reserve (50 to 85 percent $M\dot{V}O_2$);

b) The duration of training should be 15 to 60 minutes of continuous aerobic activity;

and

c) Training should be conducted 3 to 5 times per week.

Type or Mode of Activity:

A large number of training modes are available to the individual. The selection of an activity is usually made on the basis of the individual's interests and objectives and the level of skill required for the activity. The available information comparing the effects of the various type of training indicates that the training responses are independent of the mode of activity if the total energy expenditure is kept constant (2, 3, 64, 66, 69). In order to develop cardio-respiratory health and fitness the activity must be of an endurance nature that uses large muscle groups, and that can be maintained continuously (2, 3, 64, 66, 69. 96).

The relative value of swimming, jogging, circuit weight training and calisthencis/endurance games activities in developing cardio-respiratory fitness for healthy middle-aged adults is of particular concern in this study.

Swimming

There is a paucity of information concerning the value of swimming as an activity for developing cardio-respiratory fitness in sedentary middle-aged men (72). Despite this, swimming is an activity that is recommended by the American College of Sports Medicine for developing endurance fitness in healthy adults (2).

Swimming training has been found to increase the aerobic power of the athlete. This increase in aerobic capacity is related specifically to the task of swimming with little modification of $M\dot{V}O_2$ during running or other non-related tasks (39, 72, 76, 91).

Evidence obtained from champion Masters swimmers indicates that they maintain their body structure characteristics and performance capabilities from youth through middle age more effectively than their non-swimming peers (83, 87). Their physiques were very much like swimming champions of 25 years ago and also much like swimming champions of today (74).

Swimmers characteristically have enlarged lung capacities, and it is thought that swimming training may increase these physiological characteristics. This is due to a large percentage of the vital capacity being used in the breathing pattern of swimming exercise (72, 79, 80, 85).

The majority of studies in swimming have been with Masters swimmers and young moderately or highly trained subjects. Therefore the responses of previously sedentary middle-aged men to training of this type are relatively unknown (72).

Jogging:

The activity of jogging has been shown to improve cardio-respiratory fitness and body composition parameters (30, 31, 36, 45, 50. 51. 52. 62. 65. 66. 67. 68. 71, 75, 96, 100, 101, 104). This type of exercise develops maximal aerobic power, measured by increased $M\dot{V}O_2$, both in absolute terms and in relation to body weight (30, 31, 36, 50, 51, 62, 65, 66, 67, 68, 71, 100, 104).

Jogging also increases the efficiency of the cardio-respiratory system at submaximal levels of work as indicated by decreased pulse rate, ventilation rates and oxygen uptake at standardised submaximal work loads (36, 96, 100). This suggests more efficient oxygen transport, with less strain on the cardiovascular system and functional reserve, (the difference between the resting and maximum levels of a physiological response).

Body composition changes that occur with jogging regimes are a decrease in body weight, skinfold thickness and absolute and relative body fat (51, 52, 65, 66, 75, 99, 101). Lean body mass remains relatively unchanged following a jogging programme (101), with a net result of decreased body weight (51, 52, 65, 101).

Circuit Weight Training:

Traditional weight training, a programme of high resistence, low repetition exercises designed to develop strength, has no positive influence on the circulatory system which might improve endurance fitness (2, 78). However, circuit weight training, a programme of low resistance, high repetition exercises, is an effective general conditioning activity for improving body composition, strength, endurance and flexibility (30, 32, 52, 98, 99, 102). The most specific effect of circuit weight training is increased muscular strength and changes in body composition, with only a small increase in aerobic power (30, 32, 99, 102). Changes in body composition occurring with this type of training are decreased fat weight and increased lean body mass. The increase in lean body mass is greater than the decrease in fat weight therefore an increase in body weight may occur (32, 52).

The energy expenditure of circuit weight training is highly correlated with body weight and has been found to approximately equal jogging at 5 mph and cycling at 11.5 mph, indicating that HR and $\dot{V}O_2$ intensities during circuit weight training are close to the minimum threshold levels for improving cardio-respiratory fitness. It has also been found to result in a decrease of body fat even if diet and other exercise habits remain unchanged (100).

Calisthenics/Endurance Games:

There is little information concerning the value of calisthenics alone as a method of developing cardio-respiratory fitness. The majority of research has incorporated calisthenics activities with some other exercise, such as jogging (38, 44, 60, 62, 75, 88).

Moderate calisthenic programmes increase cardio-respiratory efficiency at submaximal work levels (44, 60). Calisthenic programmes associated with jogging increase work capacity and muscle mass and decrease body fat (62, 87). The increase in $M\dot{V}O_2$ has been found to be slightly lower than that found from programmes involving other activities (60). This is presumably because of a lower total energy expenditure with this type of exercise. It is possible that a greater response may be obtained from a calisthenics programme incorporating endurance games activities.

Initial Level of Fitness:

The magnitude of improvement attained in certain physiological parameters with training is related to the initial level of fitness of the subjects (1, 12, 35, 60, 65, 80, 82, 83). Individuals of lower initial levels of fitness establish greater gains than those with higher aerobic power at the onset of training (1, 60). Training studies which have subjects of both high and low levels of initial aerobic power may have results that are biased by the relatively small changes that will be observed in the subjects of higher initial fitness levels (69). Therefore the initial level of fitness of the subjects is an important consideration in the analysis of results of such studies.

The training response is not only related to the initial fitness level but also to the intensity of the training regime relative to the individual's aerobic power at the onset of the programme (83). Therefore activities of low energy expenditure may be effective in improving the endurance fitness of subjects with low initial fitness.

Training Responses with respect to Age:

Age does not appear to influence the degree of physiological change resulting from training and adult males aged 46 to 59 years have demonstrated changes with exercise as favourable as those of younger men (50).

The improvements of older subjects tend to be less when their low aerobic power at onset is taken into account. There is a less marked increase in absolute terms for middle-aged and older subjects which must be partially explained by aging (1, 36, 44, 53, 74, 78). Despite this, the middle-aged sedentary subjects have the same relative ability to increase their $M\dot{V}O_2$ as younger individuals (80).

Increased aerobic power in younger subjects is accounted for by equivalent increases in the arterio-venous oxygen difference and cardiac output. In middle-aged athletes the arterio-venous oxygen difference is smaller than that of younger athletes (36, 53). The less pronounced increase in $M\dot{V}O_2$ of older individuals with training is probably due to their lesser ability to increase the arterio-venous oxygen difference with training (35, 36, 53).

The changes in physical work capacity and body composition that occur with regular physical activity in middle-aged subjects appear to decelerate the usual trends seen with aging (88).

MODIFICATION OF CARDIOVASCULAR DISEASE RISK FACTORS WITH TRAINING

Cardiovascular diseases are the most common cause of death in Australia, contributing to approximately 50 percent of all deaths (8). Coronary heart disease, the formation of atherosclerosis within the coronary arteries, is the most common single cause of death in Australia (8, 57). Heart disease has no solitary cause, but rather there are many factors that may be considered responsible. When present these factors place the individual at an increased risk for premature or advanced development of coronary heart disease. The primary risk factors are hypertension, hyperlipidemia and cigarette smoking. Secondary risk factors include family history, obesity, physical inactivity, diabetes mellitus and hyperglycemia (3). Exercise may have a place in the prevention of cardiovascular disease if it is proven that it reduces certain risk factors or has an independent beneficial effect. The risk factors that are most likely to obtain a beneficial effect from a physical activity programme are hyperlipidemia, hypertension, obesity and obviously physical inactivity.

Hypertension:

Hypertension, or high blood pressure, is a disease that is displayed by an unstable or persistent elevation of blood pressure above the normal range (57, 64).

The effect of exercise on hypertension is unclear, as indicated by the equivocal results of various studies. In some cases it has been shown that exercise modifies resting systolic (60) or diastolic blood pressure (28, 46) separately, or decreases both (51, 104). Mean blood pressure has also been shown to be reduced at rest and during standardised submaximal work loads with physical training

(35, 36, 60, 81). Contrary to these results are the studies that have shown no changes in blood pressure following training (31, 66, 96, 100). The majority of these latter studies have involved subjects who had normal blood pressure prior to the start of the exercise programme (66, 96, 100). Investigations involving hypertensive individuals have shown that following a training programme, greater decreases in systolic and diastolic blood pressure at rest and during submaximal exercise, occurred in these subjects than those with normal blood pressure (10, 13, 17, 71).

Individuals who have remained physically active through middle age and later life have lower blood pressure than the population standard for their age (32, 44), reiterating the beneficial effects of exercise in aiding the control of blood pressure.

Hyperlipidemia:

The most significant blood fats related to the onset of cardiovascular disease are cholesterol and triglycerides (14, 63). The levels of these blood fats increase significantly with age (25) and high levels in the blood increase the risk of coronary artery disease (57).

Contradictory results exist concerning the effects of exercise on cholesterol levels. Some studies have shown that physical training decreases serum cholesterol levels (15, 25, 28, 34, 37, 46, 49, 50, 71, 89) while other research indicates that there is no change in the cholesterol levels with training (10, 16, 38, 47, 54, 63).

In contrast there is a consensus of information on the effects of exercise upon serum triglycerides. It appears that endurance training decreases the level of serum triglycerides in subjects with both normal and elevated triglyceride levels (10, 16, 28, 37, 38, 40, 63). The serum triglyceride decreases significantly within 24 hours of the first exercise session and there appears to be a cumulative response with further training sessions (10, 63). This decrease is short lived as within 96 hours of physical activity the serum triglyceride levels return to base line levels (10). Therefore there is a need to train approximately three times per week in order to maintain a reduced level. Exercise of low to moderate intensity, not sufficient to produce a cardiovascular training effect, has no effect on the serum triglyceride levels (71, 89).

A decrease in plasma triglyceride has been associated with an increase in high density lipoprotein (HDL) (40, 47, 97). This substance may facilitate cholesterol removal from the tissues, preventing the accumulation of lipids in the arterial wall and thus slowing the atherosclerotic process (48). An increase in HDL with physical training has been found to be associated with the total amount of training done per week (47). High density lipoprotein concentration is also inversely related to cigarette smoking, relative weight and total or cumulative coronary risk rating (97).

An inverse relationship exists between very low density lipoprotein (VLDL) and HDL (47). With prolonged heavy exercise the blood lipid concentration of low density lipoprotein (LDL) decreases, the major reduction occurring in VLDL (16, 26). A decline in the level of VLDL cholesterol occurs in subjects with both normal and elevated blood lipid levels as a result of physical training (40).

Although a causal relationship has not been established, the increase in HDL and decrease of triglyceride levels may be mechanisms by which exercise protects against the development of coronary heart disease (38, 40).

Obesity:

Marked obesity is highly related to sudden death and angina, independent of other cardiovascular risk factors (29, 42, 64). Obesity has also been related to high blood pressure and diabetes (64).

Physical activity has been shown to result in a decrease in skinfold thickness (28, 31, 38, 65, 99) and percent or relative body fat (27, 30, 52, 66, 91, 100, 101, 102), and an increase in body density (28, 38). In these ways exercise is able to prevent or positively modify obesity, and thereby may decrease the risk of premature coronary heart disease.

Extensive research has identified the risk factors associated with heart disease. These factors do not singularly influence the risk of developing coronary heart disease as they are interrelated, and there is a greatly increased risk of cardiovascular diseases when multiple factors are present (14, 29, 64). Some of the risk factors, notably hypercholesterolemia, obesity and hypertension, increase with age (14). If exercise does effectively modify these factors, physical activity may be of particular importance in the prevention of coronary artery disease later in life (33, 45).

PURPOSE OF THE STUDY

The purpose of this study is to evaluate the comparative benefits of four different activities popular in the Ballarat region (jogging, swimming, circuit weight training and calisthenics/endurance games). The study will examine the change in various anthropometric, physiological and biochemical parameters, important in health related fitness, when these activities are performed within the guidelines established by the American College of Sports Medicine for the quantity and quality of exercise necessary to improve the fitness of healthy adults.

CHAPTER 2

PROCEDURES

SUBJECTS

Sixty-five males from the Ballarat community, aged twenty-seven to forty-eight years, who had been sedentary for at least two years volunteered to participate in the study. The subjects signed a document giving their informed consent for participation in the project (See Appendix A). All potential subjects were required to have a full medical examination prior to final entry into the programme. A standard document concerning the nature of the programme was taken by each volunteer to his physician (See Appendix B).

ADMINISTRATION OF TESTS

A full functional fitness assessment of each subject was carried out immediately prior to commencement of the programme; after eight weeks; and after sixteen weeks of regular activity.

All testing sessions were conducted in the Exercise Physiology Laboratory at the Department of Physical Education, Health and Recreation Studies within the Ballarat College of Advanced Education. Experienced testers were used to collect specific anthropometric and physiological data.

FITNESS ASSESSMENT PROFILE

Height (cm)

Each subject's height in centimetres was measured using a Holstain stadiometer with the subject standing in the anatomical position (See Figure 1).

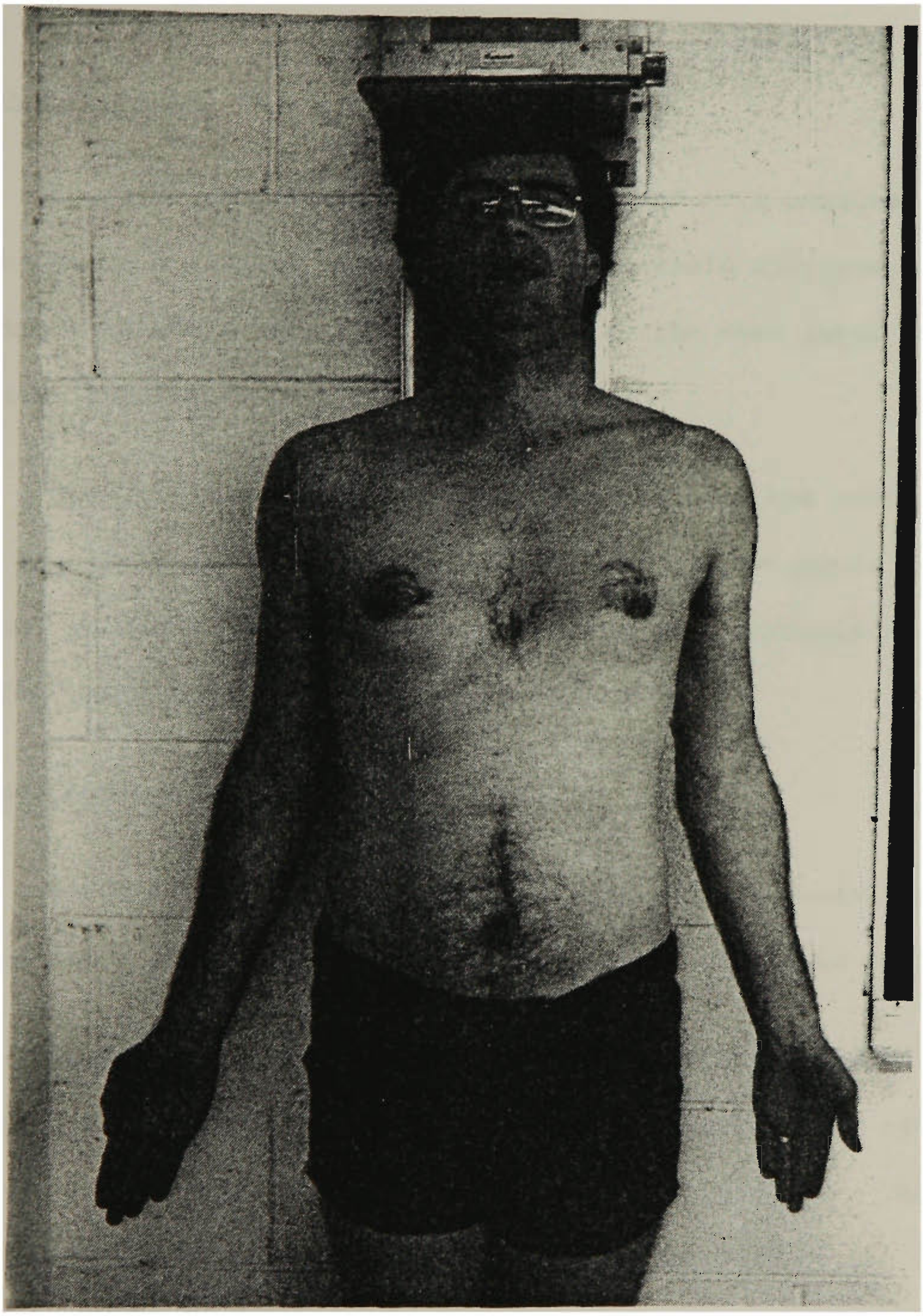


Figure 1: Measurement of height.

Weight (kg)

Each subject's weight ($\pm$ 0.1 kg) was measured with the subject standing in the centre of Seca scientific scales (model no. 578152) (See Figure 2).

Blood Pressure (mmHg)

Systolic and diastolic blood pressures were measured with the subject in a sitting position with an anaeroid sphygmomanometer using a standard cuff on the left arm at the same level as the heart (See Figure 3).

Systolic blood pressure (SBP) was taken as the cuff pressure at the first phase (commencement) of the Korotkov sounds. Diastolic blood pressure (DBP) was recorded as the cuff pressure at the fifth phase (cessation) of the Korotkov sounds.

Body Composition (Percent Body Fat)

Percent body fat was predicted from skinfold measurements which provide data on the amount of adipose tissue in the human body.

Skinfold thickness was measured on the right side of the body with a Harpenden skinfold caliper which is designed to exert a constant pressure of ten grams per square millimetre. The sites measured were the chest (a diagonal fold one-half of the distance between the anterior axillary line and the nipple), and the axilla (a vertical fold on the mid-axillary line and level with the nipple) (64). (See Figures 4 and 5).

These measurements were converted to body density and thence to body fat, using the following formulae:

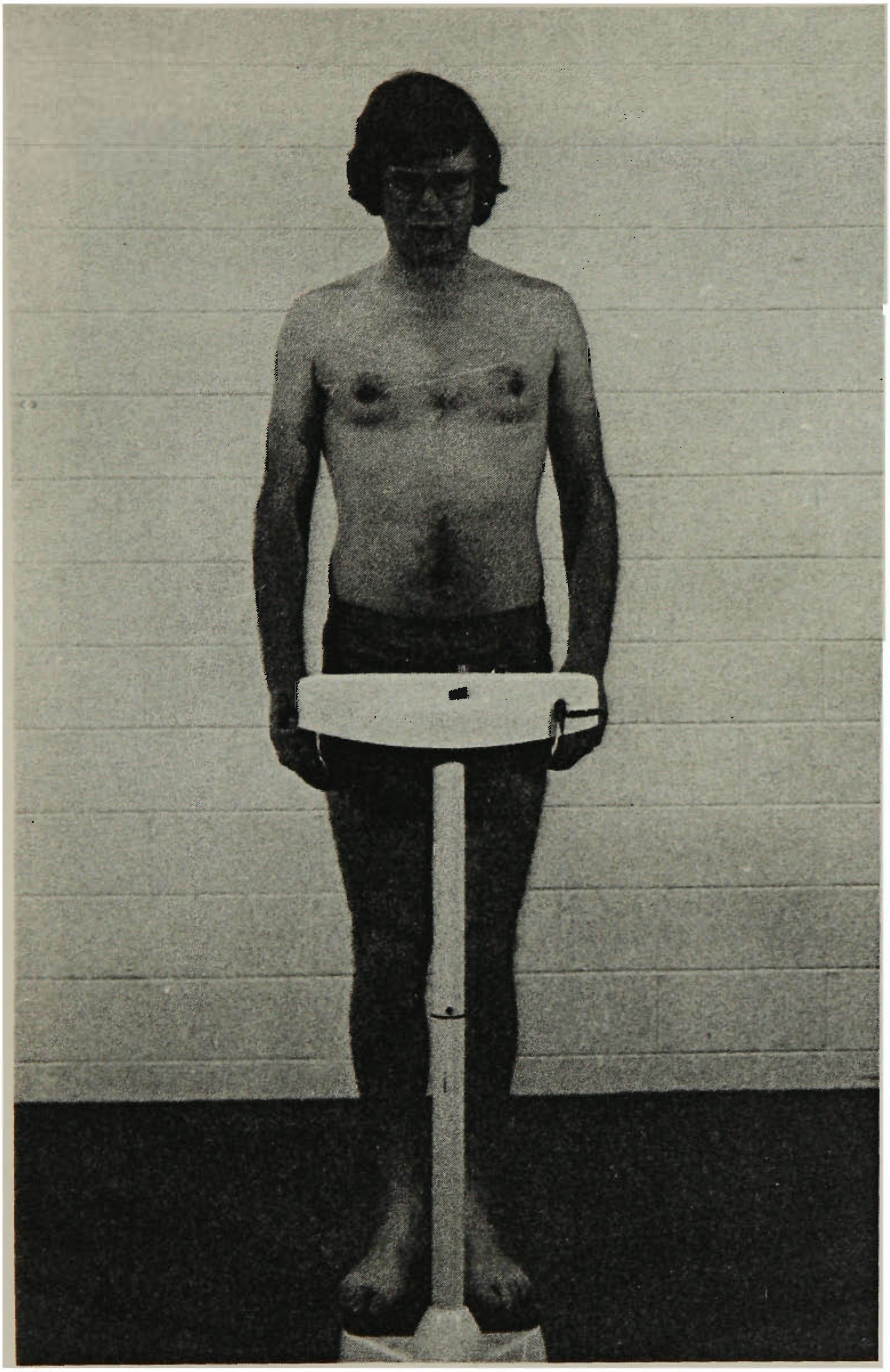


Figure 2: Measurement of weight.

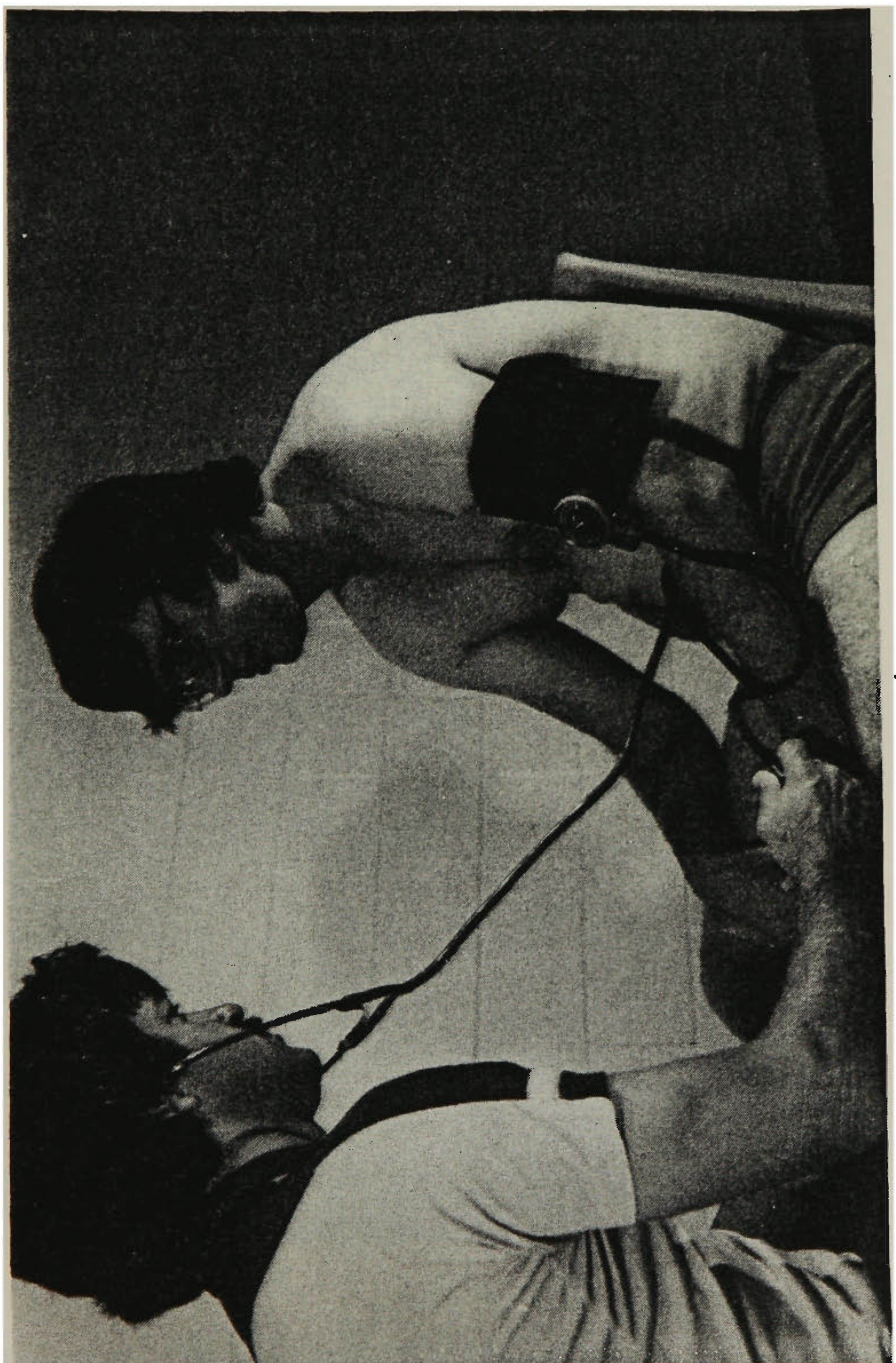


Figure 3: Measurement of blood pressure.

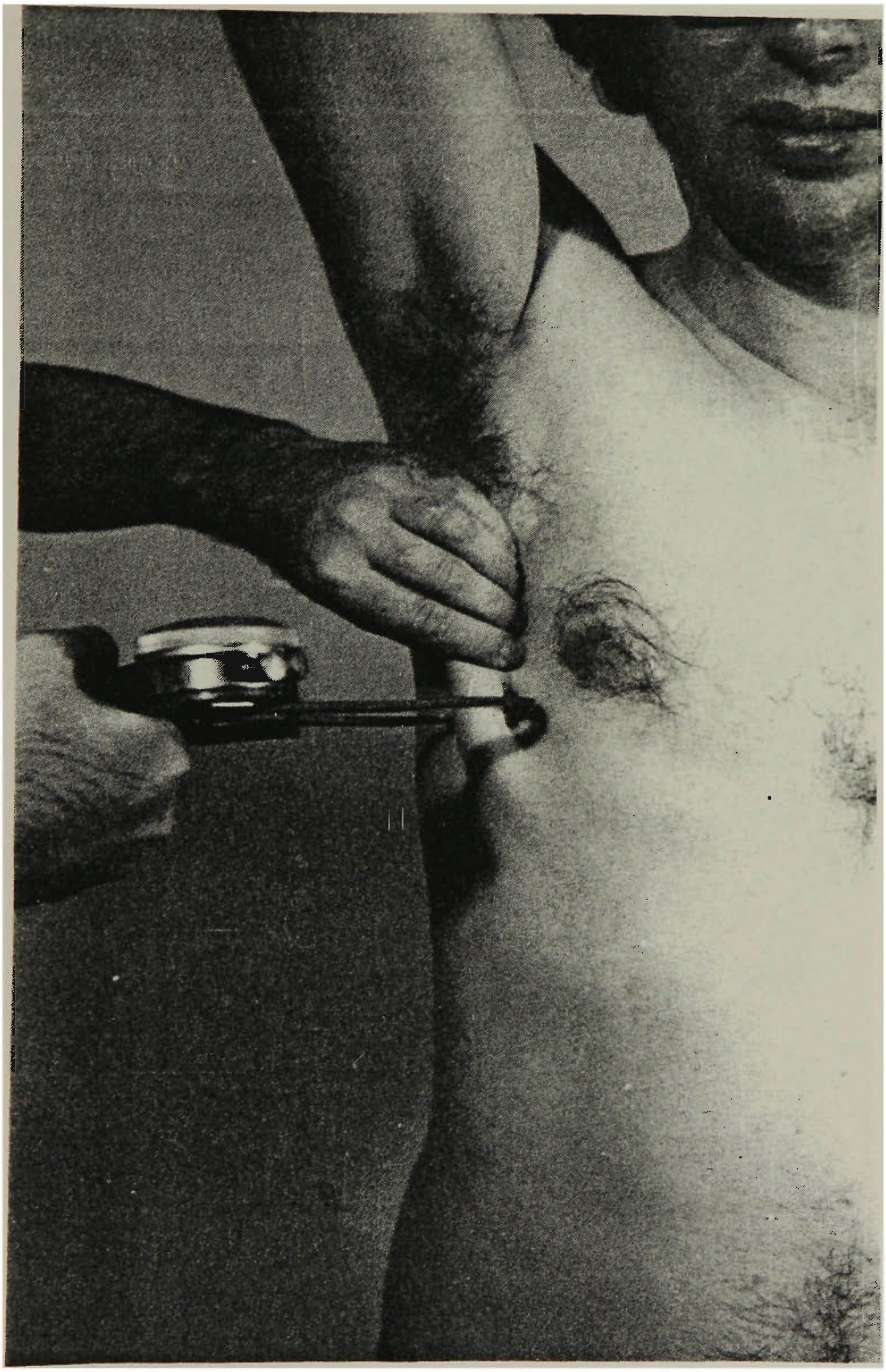


Figure 4: Measurement of axilla skinfold thickness.

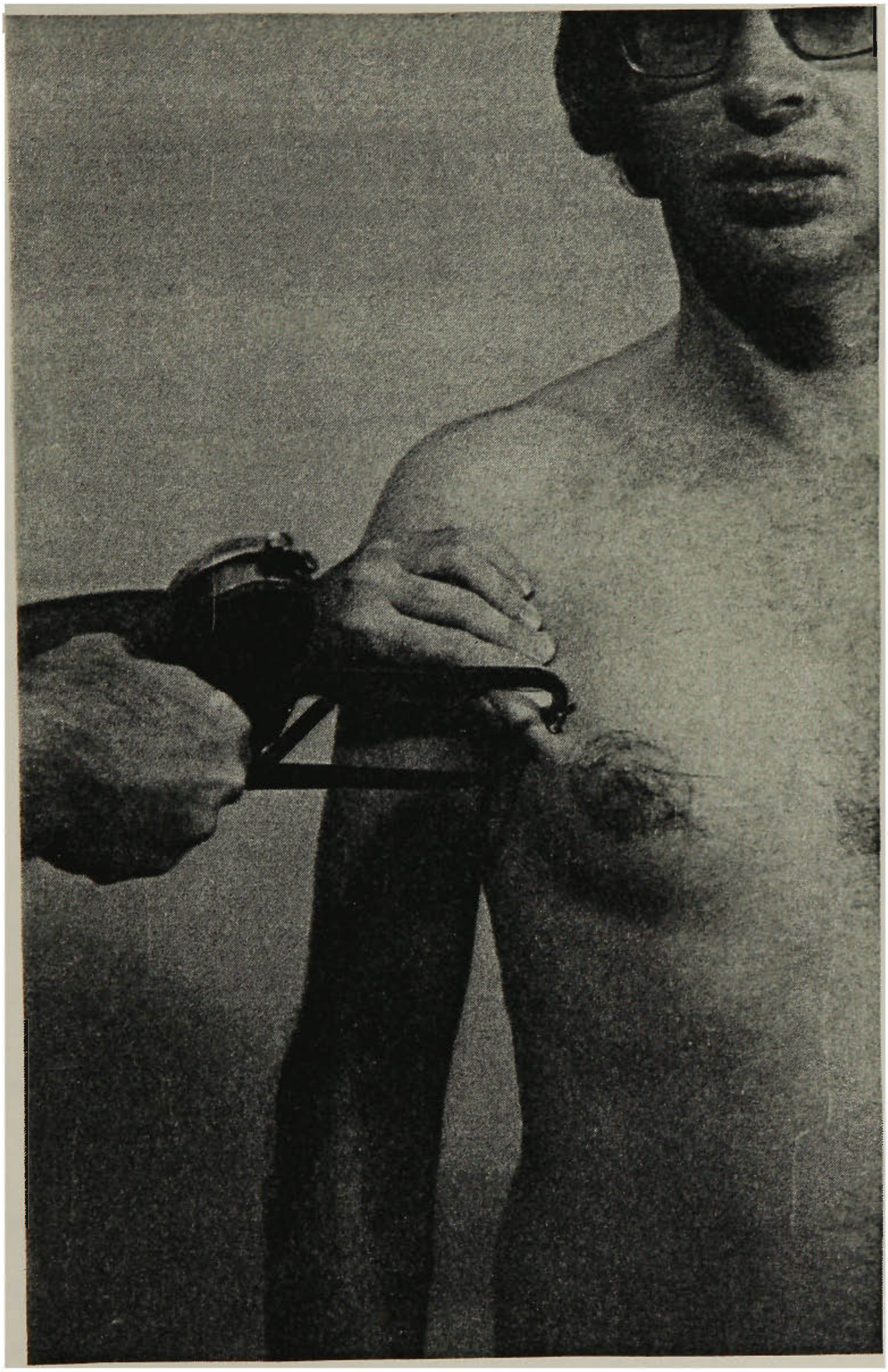


Figure 5: Measurement of chest skinfold thickness.

$$\text{Density} = 1.0766 - 0.00098 \times \text{chest} - 0.00053 \times \text{axilla} \ (70)$$

$$\text{Percent Fat} = \frac{4.950}{\text{Density}} - 4.50 \times 100 \ (64)$$

Lung Function

Forced vital capacity (FVC) and forced expiratory volume in one second ($F.E.V_{1.0}$) were measured on a Vitalograph single breath wedge bellows dry spirometer (See Figure 6). From these two measurements the functional ratio $F.E.V_{1.0}/F.V.C.$ ($F.E.V._{1.0}\%$) was determined.

Subjects were instructed to take one or two normal breaths followed by a maximal inspiration, and then to place their lips completely around the mouthpiece and exhale vigorously. The importance of moving the greatest possible volume of air, as quickly as possible, was emphasised. Each subject was allowed two trials without recording.

The stylus was then set on the STYLUS START point. Each subject was given two recorded trials. If there was a difference of 0.3 litre or greater between these two, a third trial was performed. Following each test trial the Vitalograph recording plate was reset at the starting point.

Endurance Fitness

Each subject's endurance fitness level was determined by a submaximal bicycle ergometer test, where the physical work capacity at a heart rate of 170 beats per minute (PWC_{170}) was calculated (See Figure 7). This test is based on the linear relationship between steady state pulse rates, and the workloads producing these pulse frequencies. It enables prediction of the work load required to elicit a steady heart rate of 170 b.p.m.

The bicycle ergometer saddle height was adjusted to permit slight knee flexion on the extreme downstroke of the pedal.

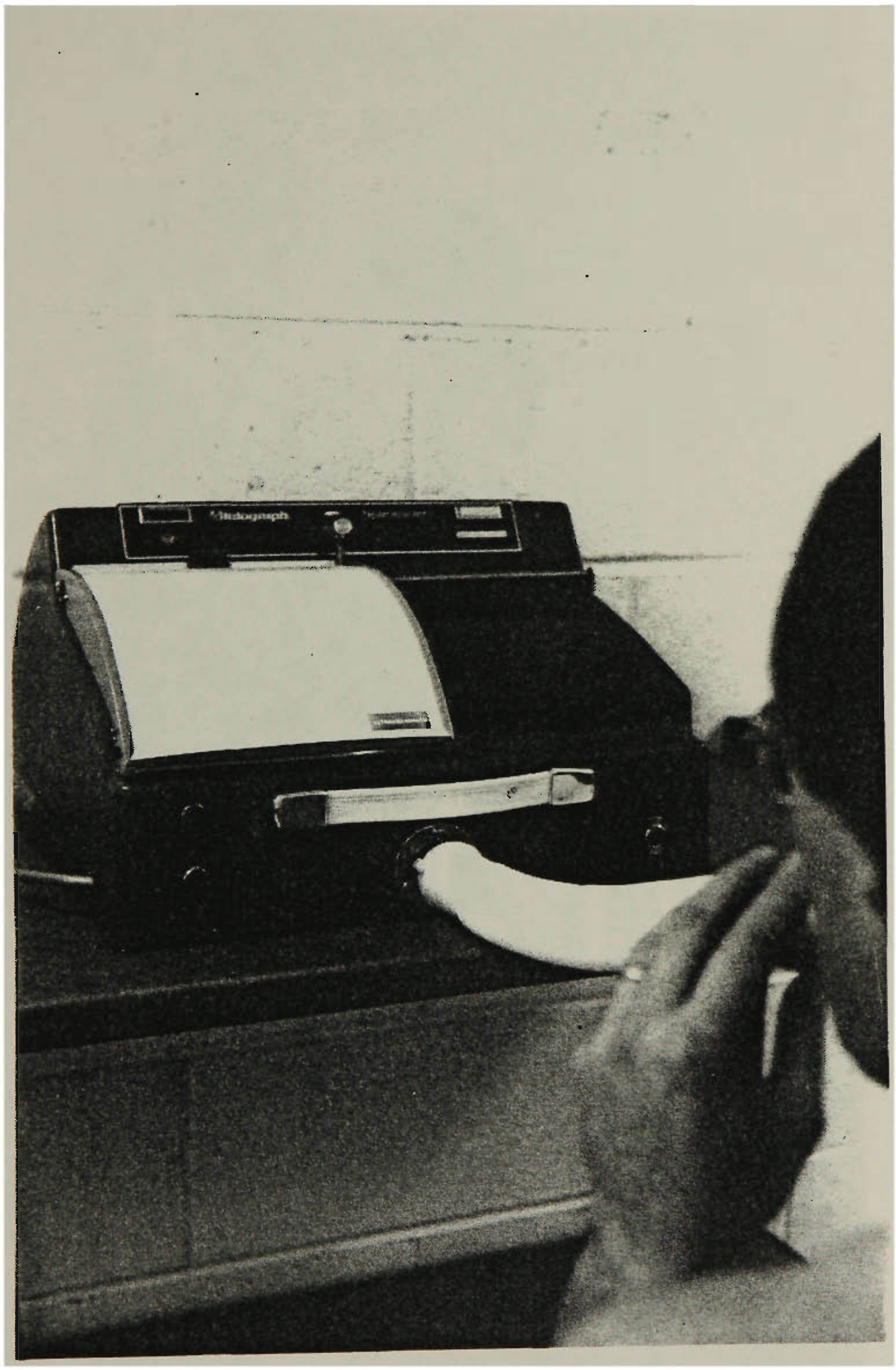


Figure 6: Measurement of lung function - the Vitalograph.

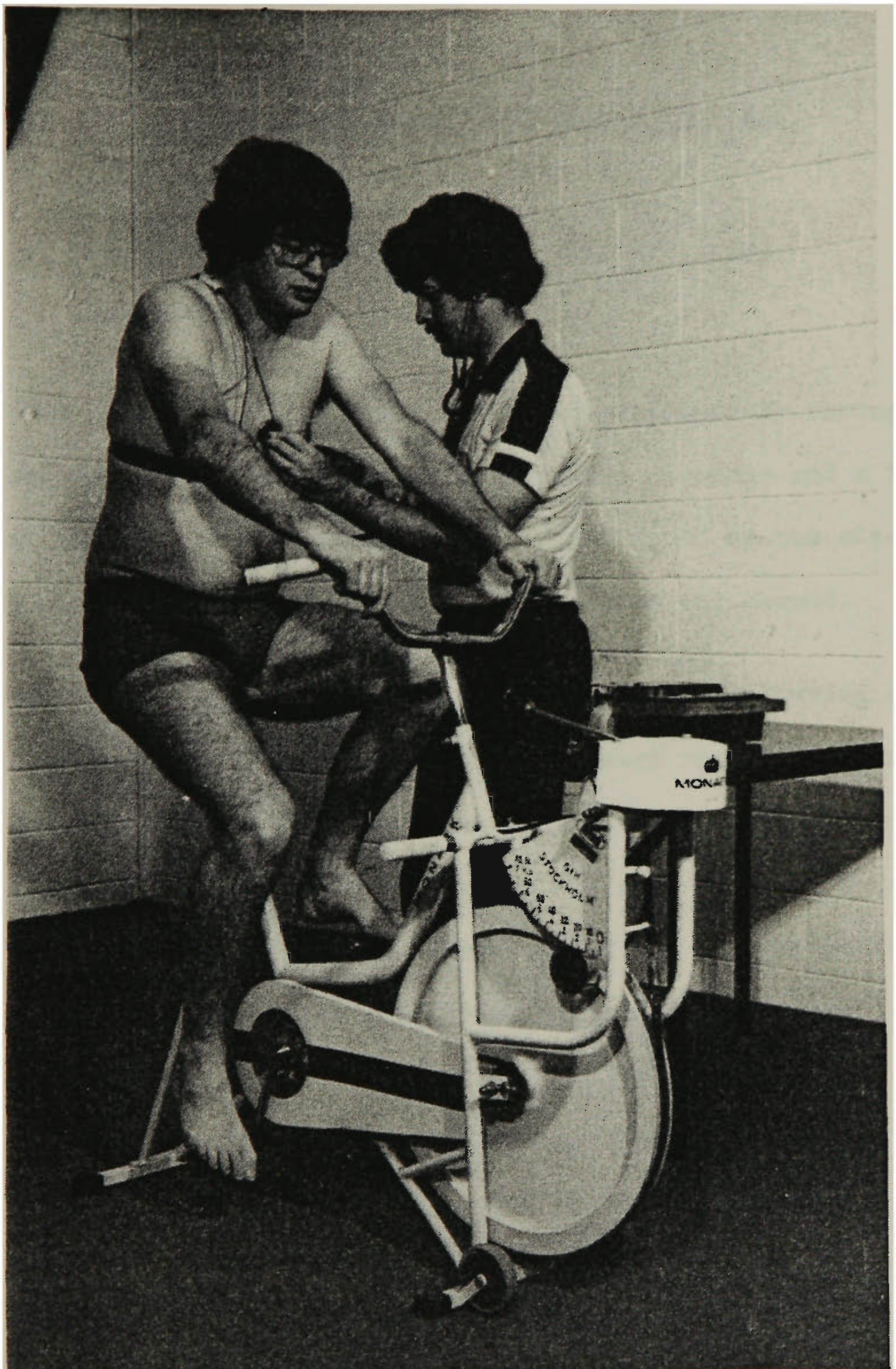


Figure 7: Measurement of endurance fitness – the PWC_{170}.

Each subject was prepared for an electrocardiogram using a transthoracic bipolar chest lead with the following electrode sites:

a) fifth intercostal space, mid clavicular line, right side (R.A.)

b) fifth intercostal space, mid clavicular line, left side (L.A.)

c) sixth intercostai space, mid axillary line, left side (R.F.)

The electrocardiogram was monitored continuously throughout the test by use of a Simonsen weel (Type DS521) diascope and a Toshiba (Model ECG-01K) electrocardiograph. Paper speed of the electrocardiogram was set at twenty-five millimetres per second.

The PWC_{170} is a multistage submaximal test consisting of three consecutive four minute workloads. The heart rate was recorded at the end of each minute of the test by the use of a stethoscope on the chest. The time for thirty beats was measured with a stopwatch and converted to beats per minute with the use of a conversion chart. Desired heart rate levels after four minutes at each work level were:

Work level 1	115 to 130 b.p.m.
Work level 2	130 to 145 b.p.m.
Work level 3	145 to 160 b.p.m.

Following completion of the test the subjects were allowed to 'cool down' slowly with lightly loaded ($<$ 360 $kg.m.min^{-1}$) bicycle pedalling.

The PWC_{170} was determined by use of the Linear Estimation function on a Hewlett Packard HP.32E calculator from the data of workload and steady state heart rate.

Flexibility (cm)

A 'sit and reach' test was used to measure the mobility of the posterior thigh muscles (hamstrings), hips, and lower back. The subject sat on the floor with both legs together and extended straight in front, with his feet placed flat against a bench. A ruler was attached to the bench, marked in centimetre divisions on either side of a zero point where the feet contacted the bench.

The subject placed both hands on the ruler and reached forward as far as possible. The knees were kept straight with the aid of slight pressure from an assistant as the forward movement was made steadily without bouncing (See Figure 8). The subject's score, in centimetres, was taken as the furthest point reached by the extended fingers, a positive score indicating a distance beyond the feet and a negative score indicating a distance short of the feet. The best score over three trials was recorded.

Blood Biochemical Analysis

Three millilitres of blood were drawn from an arm vein following a twelve hour fast.

The Biochemistry Department at the Ballarat and District Base Hospital analysed the blood samples, determining cholesterol, triglycerides and High Density Lipoprotein-Cholesterol levels, using standard techniques with a Micromedic Automatic Pipettor/dilutor and a Centrifichem 400.

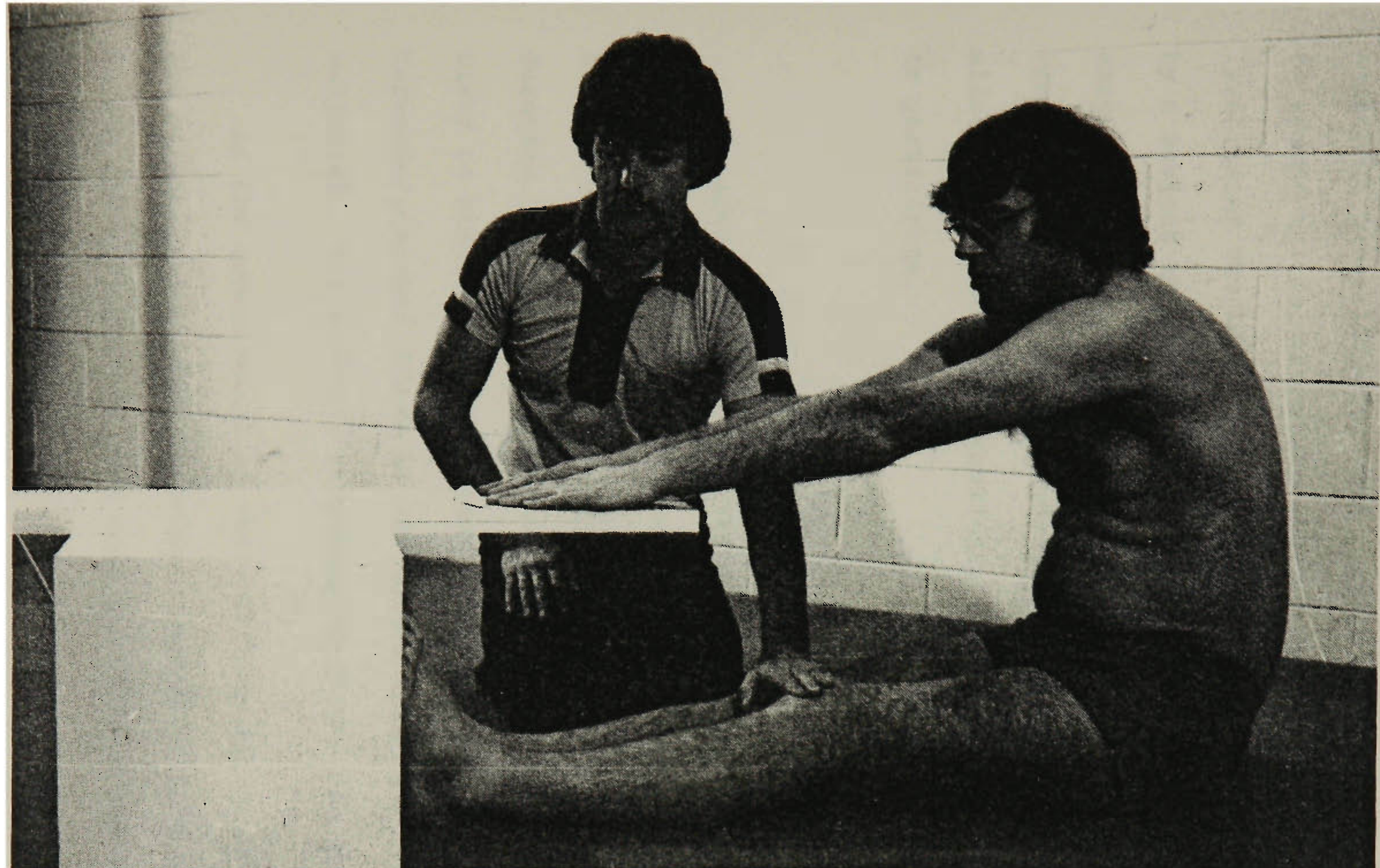


Figure 8: Measurement of lower back and thigh mobility - the sit and reach.

ALLOCATION OF ACTIVITY GROUPS

Participants were allocated at random to one of the four activity groups; circuit weight training (CWT), swimming (Sw), calisthenics/ endurance games (Cal/End) and jogging (J). This method of allocation to groups was inappropriate where a specific limiting disability (precluding the subject from one or more activity) had been specified by a subject and/or identified by their physician during the medical examination. In these cases, and in those of non-swimmers, a modified random assignment was utilised and the subjects were randomly allocated to one of the remaining activities in which they were able to participate.

TRAINING METHODS

In accordance with the recommendations of the American College of Sports Medicine (2) the subjects were requested to attend three to five sessions per week, each of fifteen to sixty minutes in duration. During each session the required training intensity was sixty to ninety percent maximum heart rate reserve (estimated by Karvonen's method (42) to be 140 to 165 beats per minute for these subjects). The activity programme continued for sixteen weeks.

At the commencement of the programme all subjects were taught the palpation technique of pulse measurement from the radial artery. During the training sessions frequent fifteen second pulse checks were conducted to ensure that the subjects remained consistently within the target heart rate range. On occasions one or two subjects were selected to wear a heart rate monitor (a Respironics Exer-sentry or a Medrad Pacex) to assist heart rate monitoring during the activity sessions.

During some training sessions selected subjects wore a Philips radio transmitter on a waist belt. Electrocardiograms from a transthoracic bipolar lead were recorded on a Toshiba (Model (ECG-01K) electrocardiograph for the determination of heart rate. The heart rate of these individuals was determined at five minute intervals throughout the training sessions.

CIRCUIT WEIGHT TRAINING

This activity was a weight training programme consisting of a series of exercises with light weights and high repetitions, supplemented by bicycle ergometer exercise.

Initially the duration of the programme was set at thirty to thirty-five minutes. The first ten minutes of the workout was devoted to a standard warm up period involving five minutes of cycling on a Repco bicycle ergometer at a work load set to elicit a heart rate of 120 to 130 beats per minute (determined from the PWC_{170} test) and five minutes of static stretching exercises (19).

Following the warm up each subject in the group worked through a series of exercises, moving continuously from one exercise to another. The initial duration of the circuit was ten to fifteen minutes.

The circuit consisted of ten exercises which were performed twice in each workout in the following sequence on a Universal Centurion 16 man station:

1. Bench Press
2. Hip Flexors
3. Shoulder Press
4. Leg Extension
5. Leg Curl
6. Sit Ups (bent knees)
7. Triceps Extension
8. Lat Pulldowns
9. Arm Curls
10. Leg Press

In the first session an appropriate training weight (50 percent of the maximum weight the subject was able to lift once) was calculated with each individual for each exercise. The repetitions for each exercise were initially set at ten and were increased over a period of time to fifteen. As the programme became easier for the subjects the weights of each exercise were increased by ten pounds. During the first eight weeks of training the number of circuits was gradually increased to a maximum of three.

Following the circuit each subject cycled on a bicycle ergometer for a further five minutes at a workload set to elicit a heart rate between 140 and 165 b.p.m. This was followed by a two minute cool down period at a work load less than 400 $kpm.min^{-1}$, and stretching exercises.

All sessions were supervised with each individual's attendance and progress being recorded.

SWIMMING

A requirement of being able to swim 50 metres continuously was set before entry to this activity programme.

All training sessions were fully supervised by a qualified swimming instructor and a daily programme was set for the group. This programme consisted of long slow distance swimming; interval training with varying distances, intensities and rest intervals; modified water games; and relays. During the initial two weeks of training, time was spent on improving stroke techniques.

For each subject a daily record of attendance, distance swum, and heart rates for each session were recorded. The distance swum per session was progressively increased during the sixteen week period.

CALISTHENICS/ENDURANCE GAMES

This activity was composed of three basic elements; a warm up, a cardiovascular conditioning period and a cool down period. All sessions were fully supervised by a competent exercise leader.

The warm up consisted of a gradual introduction to physical activity for ten minutes and included flexibility activities. Generally walking exercises were performed first, followed by slow jogging and static stretching.

During the cardiovascular conditioning period all subjects were required to be working within the target heart rate range. This section of the session generally consisted of two periods, the first consisting of circuit training, jogging, continuous calisthenic exercises to music or aerobic dance, while the second period involved such activities as modified endurance games, relays and occasionally competition circuits. The duration of the cardiovascular conditioning period was gradually increased over the sixteen weeks from ten minutes to forty minutes.

Following aerobic activity at the Target Heart Rate level, a cool down period of approximately ten minutes allowed the body to adequately return to near resting state. This was an active cool down period consisting of walking and static flexibility exercises (19). All subjects were required to measure their pulse following this period to ensure that their heart rate had returned to 100 b.p.m. or less.

JOGGING

The jogging programme was conducted at various venues around Ballarat and initially involved walking and jogging equal distances for fifteen to twenty minutes. The distance and duration were gradually increased over the sixteen weeks in such a fashion that the individuals walked less and jogged further. The final few weeks of training consisted of continuous jogging for thirty to forty-five minutes. Warm up and cool down periods of static stretching prior to and following each session were included in this programme.

Attendance, distances covered, and heart rates were recorded each session by the programme supervisor.

MONITORING LIFESTYLE FACTORS

At the commencement of the programme all subjects were requested to maintain their normal lifestyle pattern with the exception of the addition of regular physical activity over the sixteen weeks of the project.

To establish that this had been achieved, each subject completed a lifestyle analysis after four weeks and again after twelve weeks of training. This lifestyle analysis included diet, average alcohol consumption and cigarette smoking habits for two days.

From this information provided by the subjects, total energy intake (kilojoules) and the proportions of energy derived from each of carbohydrate, fat and protein food groups were calculated using a programmed Tektronix 4051 computer and literature values for individual food items (11, 20, 55, 94).

STATISTICAL ANALYSIS

Statistical analysis of the data in this study required the calculation of mean values and standard deviations, and the use of dependent t-tests, analysis of variance, analysis of co-variance and the scheffé post hoc comparison procedure. The computations for these statistical techniques were performed using either the Statistical Package for Social Sciences as operated by the Ballarat College of Advanced Education computing centre; a pre-programmed Tektronix 4051 computer; or a Hewlett Packard 32E calculator.

A level of significance of $p < 0.05$ was accepted for the dependent t-tests, analysis of variance and analysis of co-variance. As the scheffé test is the most stringent of the post hoc comparisons, a level of significance of $p < 0.1$ was accepted for the post hoc comparisons procedure.

CHAPTER 3

RESULTS AND DISCUSSION

SUBJECTS

Of the sixty-five subjects who entered the programme, thirty-five satisfactorily completed the requirements of the study, representing a retention rate of fifty-three percent. A high proportion of the total dropout occurred in the jogging group. Subjects who ceased to continue in the study were requested to give a reason for their non-compliance to the specific exercise regime.

TRAINING METHODS

JOGGING

Fifteen subjects commenced with this activity and during the sixteen weeks six withdrew from the programme due to injury or the re-occurrence of a previous injury. One of the subjects was transferred in employment and another could not participate in the final testing because of an accident unrelated to the study. Five subjects failed to meet the required level of participation, having low and irregular attendance. Therefore only two of the fifteen subjects completed this activity programme within the specified requirements. For this reason the results of the jogging group were not considered in the statistical analysis.

The high dropout rate of the jogging group would suggest that this is not a suitable activity for previously sedentary middle-aged men. One half of those who withdrew from the programme did so because of injury, predominantly lower limb musculo-skeletal overuse injuries.

CIRCUIT WEIGHT TRAINING

Eighteen subjects commenced participation in this activity. During the sixteen weeks four withdrew from the programme due to loss of interest and boredom.

SWIMMING

Sixteen subjects commenced this activity and over the sixteen weeks four participants withdrew due to lack of interest and boredom. The results of another subject were discounted as he had responded to a request for an emergency blood donation one week prior to final testing.

CALISTHENICS/ENDURANCE GAMES

Of the sixteen subjects who commenced this activity, six withdrew or were eliminated from the programme. Two withdrawals were due to injury, and one subject had to withdraw due to an inner ear infection unrelated to the activity programme but which required surgery. One subject was discounted due to low and irregular attendance, another due to participation in a marathon one week prior to final testing and one participant withdrew from the programme due to an overseas holiday.

INTENSITY OF TRAINING

The training intensity of the circuit weight training and calisthenics groups were monitored by telemetry, while for the swimming group heart rate was monitored by palpation (See Figure 9).

Figure 9 shows that the calisthenics and circuit weight training groups obtained the required intensity in approximately ten minutes and maintained the required intensity for ten minutes and thirty-five minutes respectively. The reason for the fluctuations in heart rate to levels below the minimum level of training heart rate in the calisthenics group was the nature of the activities in the particular sessions monitored. Regular pulse counting during other sessions indicated that this activity consistently elevated heart rate above the minimum training level.

The swimming group did not reach the minimum level of intensity until approximately twenty minutes into the session and maintained that level for approximately thirty-three minutes.

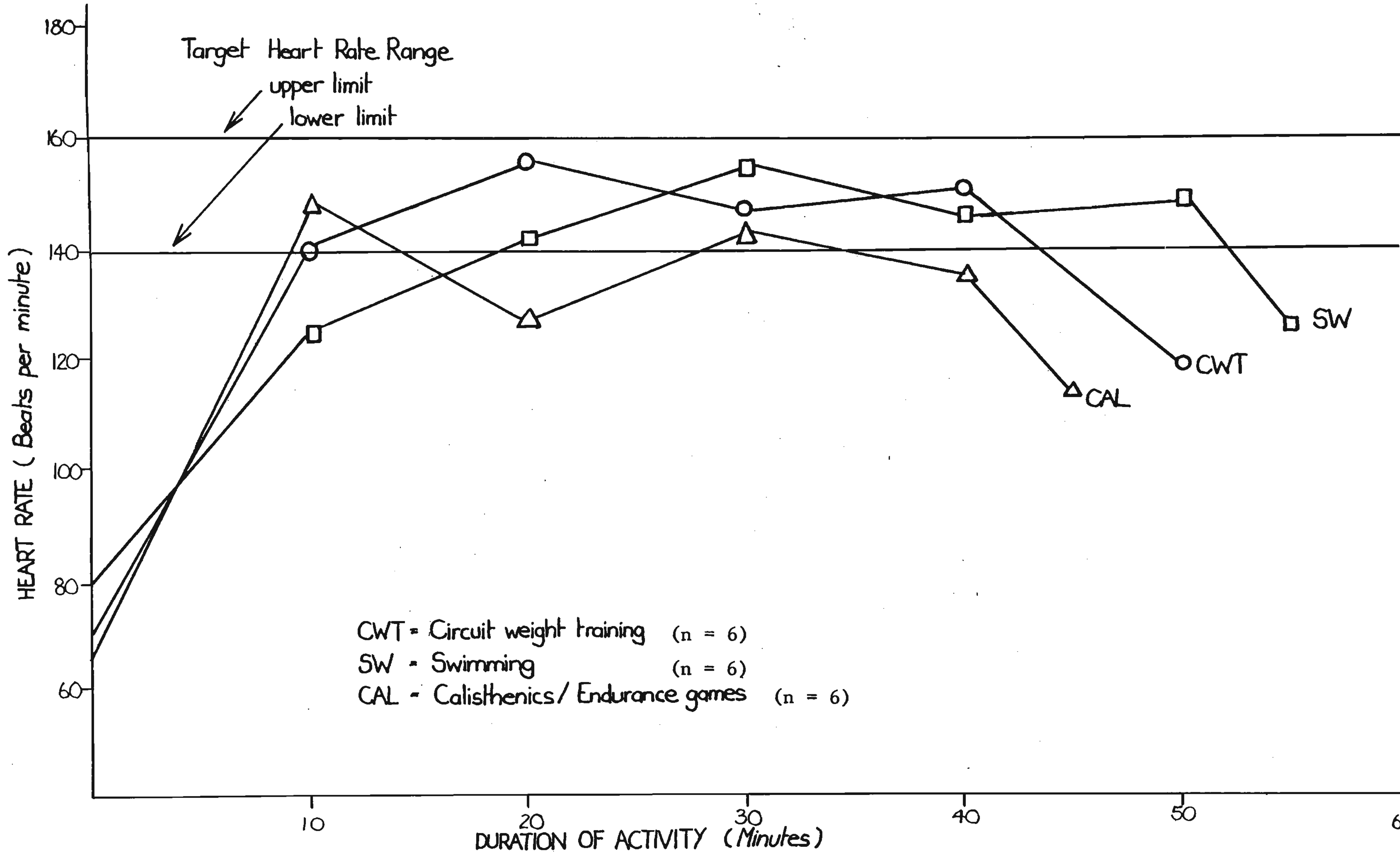


Figure 9: Average heart rates of selected subjects during activity sessions.

AVERAGE ATTENDANCE

A significant difference in average attendance was observed between groups ($F = 6.5$ $p < 0.05$) during the training period, with the swimming group having higher attendance than the other two groups (See Figure 10).

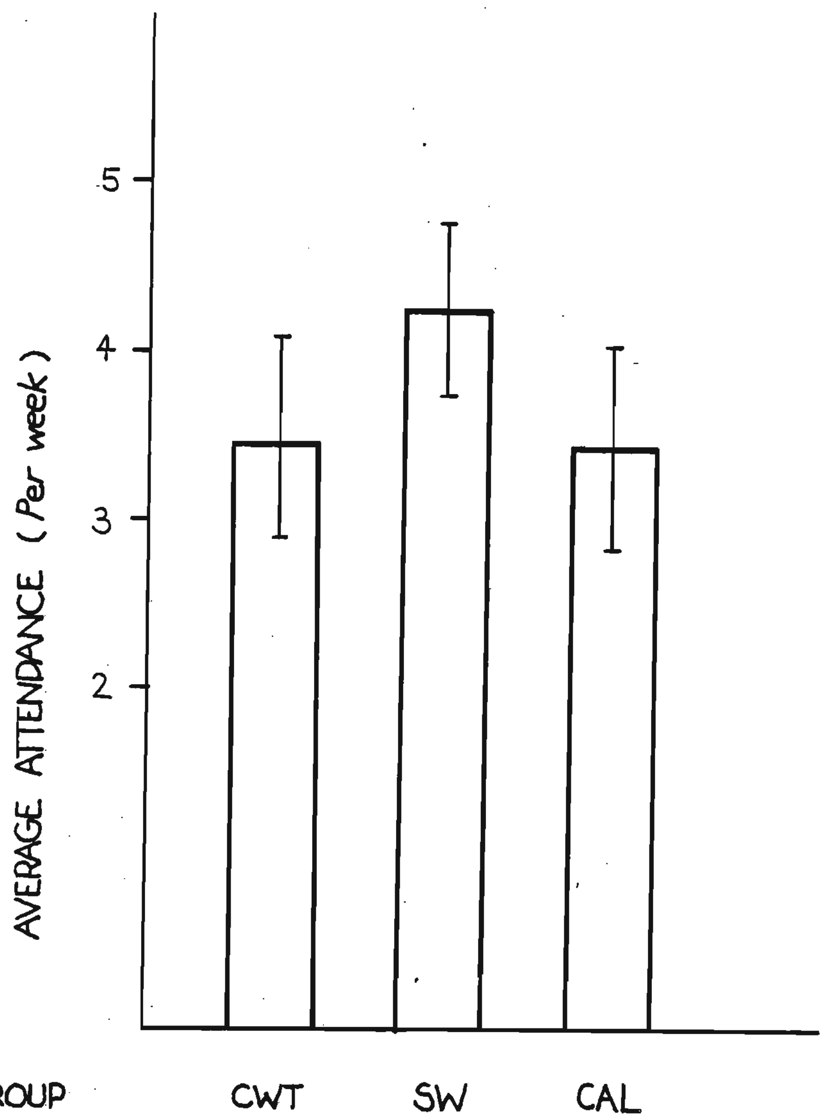
As frequency of training is one factor which might influence the magnitude of the training response, variations in the average attendance of subjects at activity sessions have been considered as a covariant along with the mode of training in the analysis of these results.

DIET

Only 18 of the 35 subjects who completed the study returned sufficient dietary information to enable a satisfactory analysis.

No significant changes were observed during the study in total energy intake or the percentage of the energy intake derived from fat. This indicates that the subjects had complied with the request at the commencement of the programme not to change lifestyle habits, with the exception of the addition of regular physical activity (See Figure 11).

As critical elements of the diet had not altered within the duration of the study, it was possible to determine the effect of exercise alone on the parameters which were measured.



CWT = Circuit weight training
SW = Swimming
CAL = Calisthenics / Endurance games
Values shown are means, bars indicate ± 1 Standard deviation

Figure 10: Frequency of attendance at training sessions during sixteen weeks of regular activity.

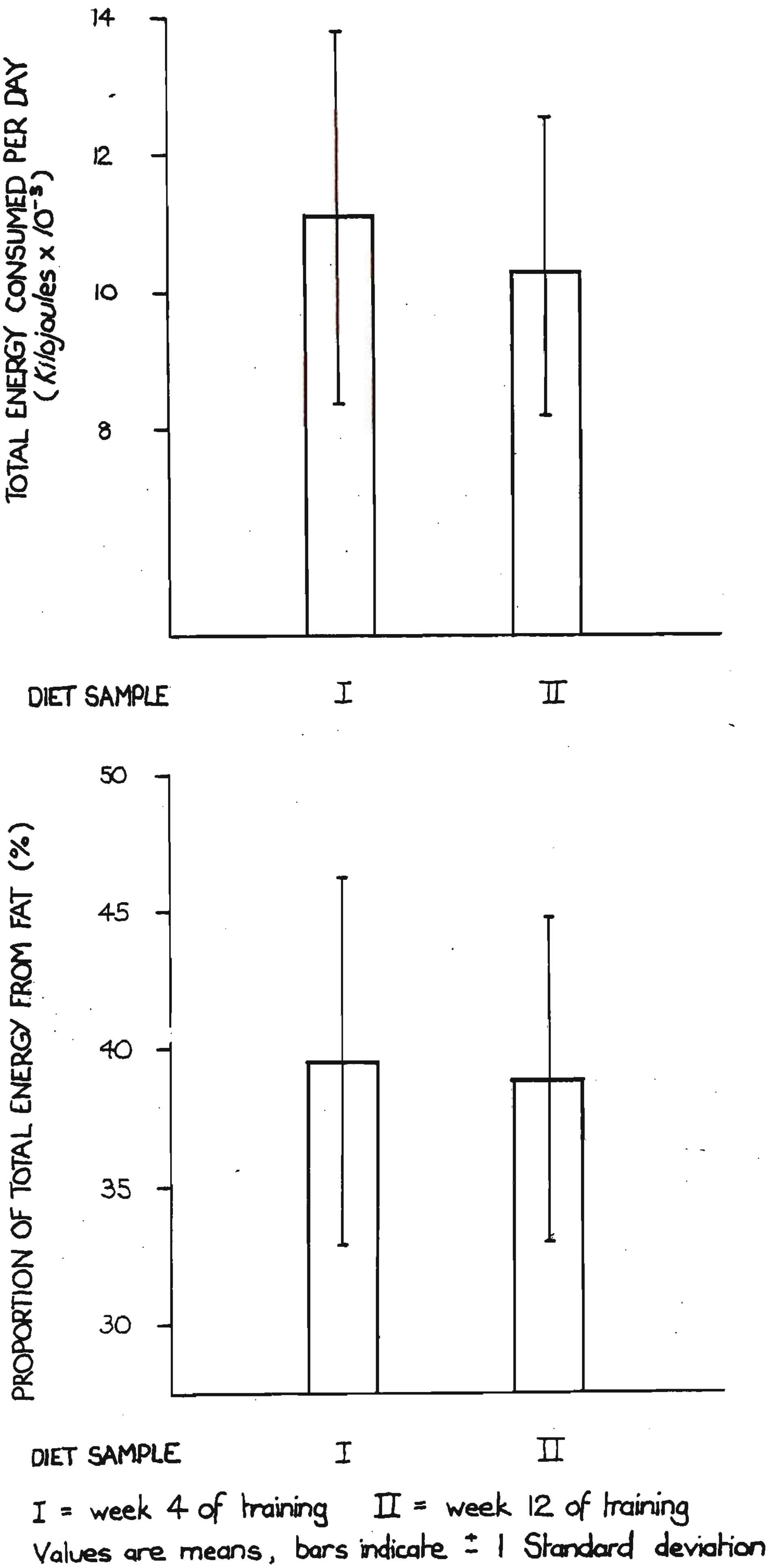


Figure 11: Diet analysis during sixteen weeks of regular activity.

ANTHROPOMETRIC PARAMETERS

AGE

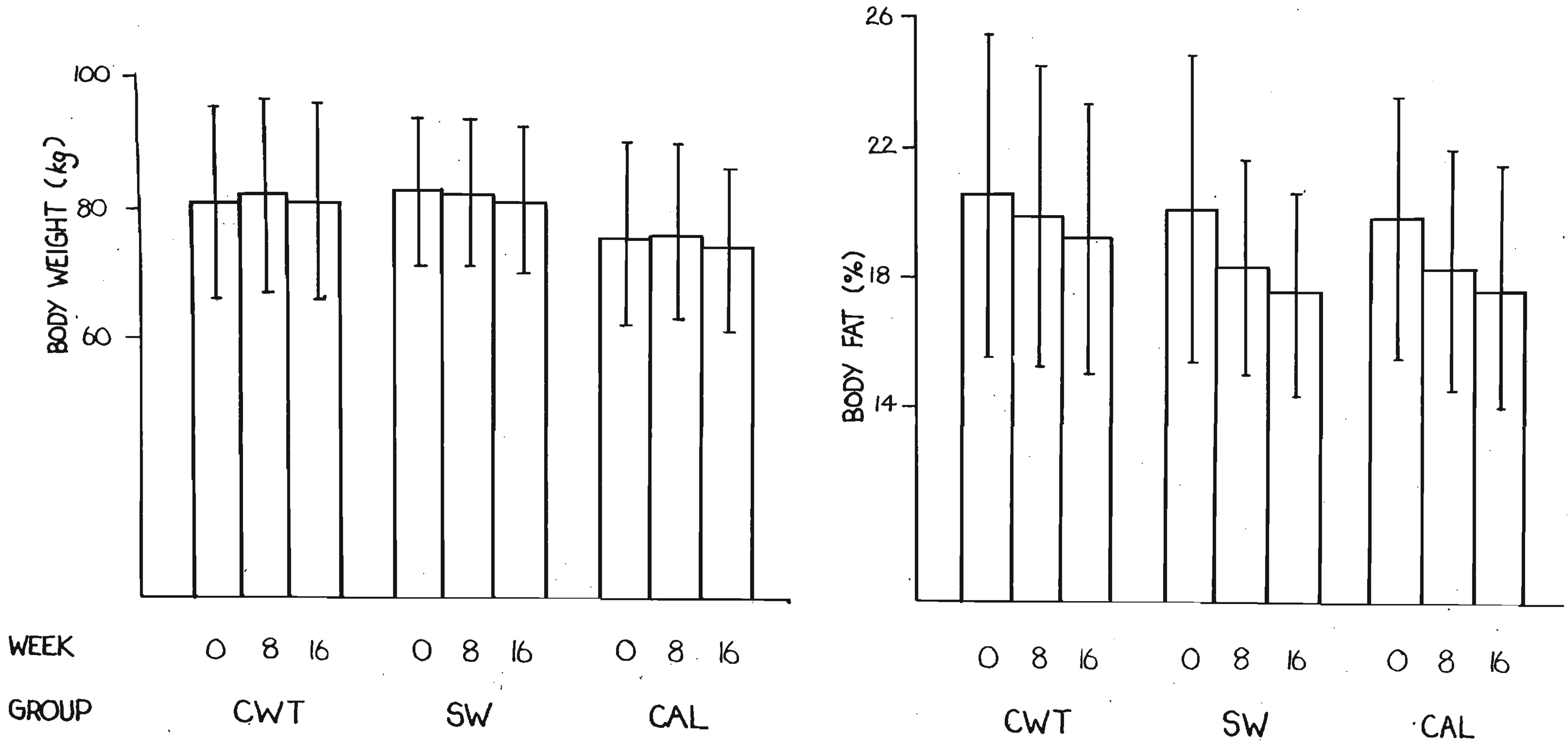
There was no significant difference in age between the groups. Therefore age differences between the groups would not be a contributing factor to changes in other physiological parameters with training (44, 74, 78).

WEIGHT

No significant differences in weight were observed between groups throughout the training period. (See Figure 12).

Other investigators have shown significant decreases (28, 52, 75, 91, 101) or no change (31, 38, 46, 81, 99, 102) in body weight with training. The result in the present study was independent of the mode.of training, contradictory to the findings of previous investigations. Other studies have shown that activities of high energy expenditure result in a decrease in body weight (28, 52, 101) while activities of lower energy expenditure (such as circuit weight training) show no change or an increase in body weight due to an increase in lean body mass (29, 52).

This indicates that in order to change body weight either a greater energy expenditure is required or perhaps that dietary modification must coincide with regular physical activity. Energy expenditure is related to intensity and duration. It is possible that the exercise in this study is sufficiently high in intensity to increase endurance fitness but does not provide a total energy expenditure sufficient to produce decreases in body weight (fatness).



CWT = Circuit weight training SW = Swimming CAL = Calisthenics / Endurance games.

Values shown are means, bars indicate ± 1 Standard deviation.

Figure 12: Changes in body weight and percent body fat during sixteen weeks of regular physical activity.

BODY COMPOSITION

Skinfold Thickness

No significant changes in either of the two measured skinfolds (chest and axilla) were observed during the training period. This finding is contrary to results of most other studies (28, 31, 38, 65, 102), although some investigators have found that training does not decrease skinfold thickness (52, 75). Gettman et al (31) found that in a twenty week jogging programme only those attending five times per week showed a significant decrease in skinfold thickness.

Percent Body Fat

Percent body fat did not differ significantly either between groups or across test sessions during the training period (See Figure 12). This result is in disagreement with those of previous studies (27, 30, 52, 66, 91, 100, 101, 102).

A decrease in percent body fat would be expected with regular physical activity within the guidelines of the American College of Sports Medicine (2). This result indicates that some factor other than exercise alone may be necessary to achieve a reduction in body fat. In the present study the fact that the subjects' total energy intake and dietary fat content did not change during the sixteen weeks of the programme may be the important factor. These findings are in agreement with those of Swenson and Conlee (91) who found that changes in body composition were influenced by caloric intake.

Therefore in the present study, and within the guidelines of the American College of Sports Medicine (2), regular activity from three to five sessions per week may not be sufficient to significantly decrease skinfold thickness or percent body fat. Reductions in skinfold measurements and body fat have been related to the total energy expenditure per session (2, 64, 69). It is possible that in this study the total energy expenditure, although sufficient to improve endurance fitness, may not have been adequate to modify body composition.

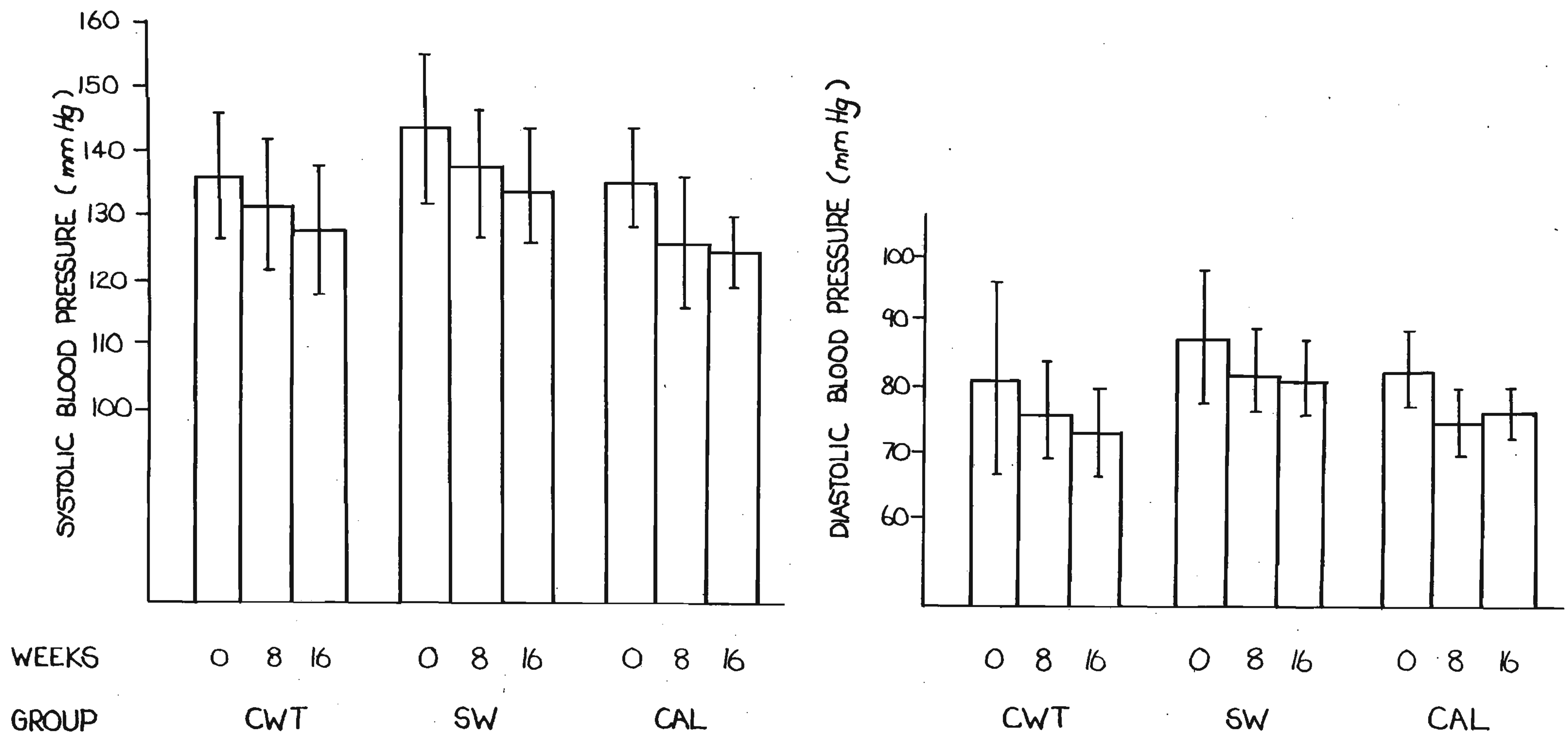
PHYSIOLOGICAL PARAMETERS

BLOOD PRESSURE

Systolic Blood Pressure

Significant differences were observed in systolic blood pressure both between groups ($F = 8.1$, $p < 0.05$) and across test sessions ($F = 8.5$, $p < 0.05$) during the training period (See Figure 13). At the commencement of training the swimming group had significantly higher systolic blood pressure than the circuit weight training group ($S = 9.7$, $p < 0.1$). Systolic blood pressure reduced significantly in all activity groups over the sixteen week training period (CWT $S = 9.1$, $p < 0.1$; SW $S = 10.1$, $p < 0.1$; CAL $S = 10.2$, $p < 0.1$). Following sixteen weeks of regular activity the initial difference in systolic blood pressure between the swimming and circuit weight training groups had disappeared. The consideration of differences in frequency of attendance at training sessions as a covariant between the groups, did not explain the greater decrease in systolic blood pressure that occurred in the swimming group.

These results are in agreement with studies which have shown that regular exercise modifies resting systolic blood pressure (51, 60, 104) and contrary to those that show no change following training



CWT = Circuit weight training   SW = Swimming   CAL = Calisthenics / Endurance games

Values shown are means, bars indicate ± 1 Standard deviation

Figure 13: Changes in blood pressure at rest during sixteen weeks of regular physical activity.

(31, 66, 96, 100). The mean systolic blood pressure of all groups was within the normal range for men of this age group (CWT 135.5 mmHg, SW 143.2 mmHg, CAL 134.6 mmHg) at the commencement of the programme.

The results of the present study show that systolic blood pressure will decrease with regular exercise in subjects with normal systolic blood pressure. This is at variance with results found by other investigators (66, 96, 100). The greater decrease in systolic pressure observed in the swimming group when compared to the circuit weight training group indicates that those with higher blood pressure may expect a greater reduction with exercise. This result is consistent with the findings of other investigators (10, 13, 17, 71).

Diastolic Blood Pressure

Significant differences in diastolic blood pressure were observed both between groups ($F = 9.7$, $p < 0.05$) and across test sessions ($F = 13.7$, $p < 0.05$) during the training period (See Figure 13). Diastolic blood pressure reduced significantly in the circuit weight training and the calisthenics/endurance games groups during the first eight weeks of regular exercise (CWT $S = 6.6$, $p < 0.1$: CAL $S = 8.2$, $p < 0.1$) and in all activity groups over the sixteen week training period (CWT $S = 9.6$, $p < 0.1$: SW $S = 6.3$, $p < 0.1$: CAL $S = 7$, $p < 0.1$). After sixteen weeks of regular activity the circuit weight training group had significantly lower diastolic blood pressure than the swimming group ($S = 8.2$, $p < 0.1$). The greater change of diastolic blood pressure in the circuit weight training group compared to swimming is the opposite of that observed with systolic blood pressure. However, all blood pressure values are within the normal range for men of their age.

The results indicate that over a period of sixteen weeks diastolic blood pressure will decrease as a response to regular physical activity. These findings are in agreement with other investigations which have shown that exercise reduces diastolic blood pressure at rest (10, 13, 28, 46, 51, 104) but are contrary to some studies which have shown no changes in diastolic blood pressure with training (31, 66, 96, 100) especially in subjects with normal blood pressure (66, 96, 100). The results obtained in this study indicate that the predominant decrease in diastolic blood pressure occurred in the first eight weeks of the programme.

The findings of this study indicate that resting blood pressure is reduced with regular physical activity, independently of the mode of activity, providing it meets the requirements of intensity, duration and frequency as specified by the American College of Sports Medicine (2). As high blood pressure is considered a risk factor in coronary heart disease, it would appear that regular physical activity is a parameter that positively modifies this risk factor.

LUNG FUNCTION

Forced Vital Capacity, Forced Expiratory Volume in one second and Forced Expiratory Volume in one second as a percentage of Forced Vital Capacity

No significant differences were observed between groups or across test sessions in any of the three spirometry measurements (See Figure 14). These results are consistent with those of previous findings showing that all three spirometry measures remain relatively constant following training (31, 33, 35, 51, 66, 67, 79, 80).

This indicates that in adults the lungs' static and more dynamic dimensions are essentially unaltered with regular physical training. Previous investigators had suggested that swimming training may increase spirometry measures due to a large percentage of the vital capacity being used in the breathing pattern of swimming (69, 76, 77, 82).

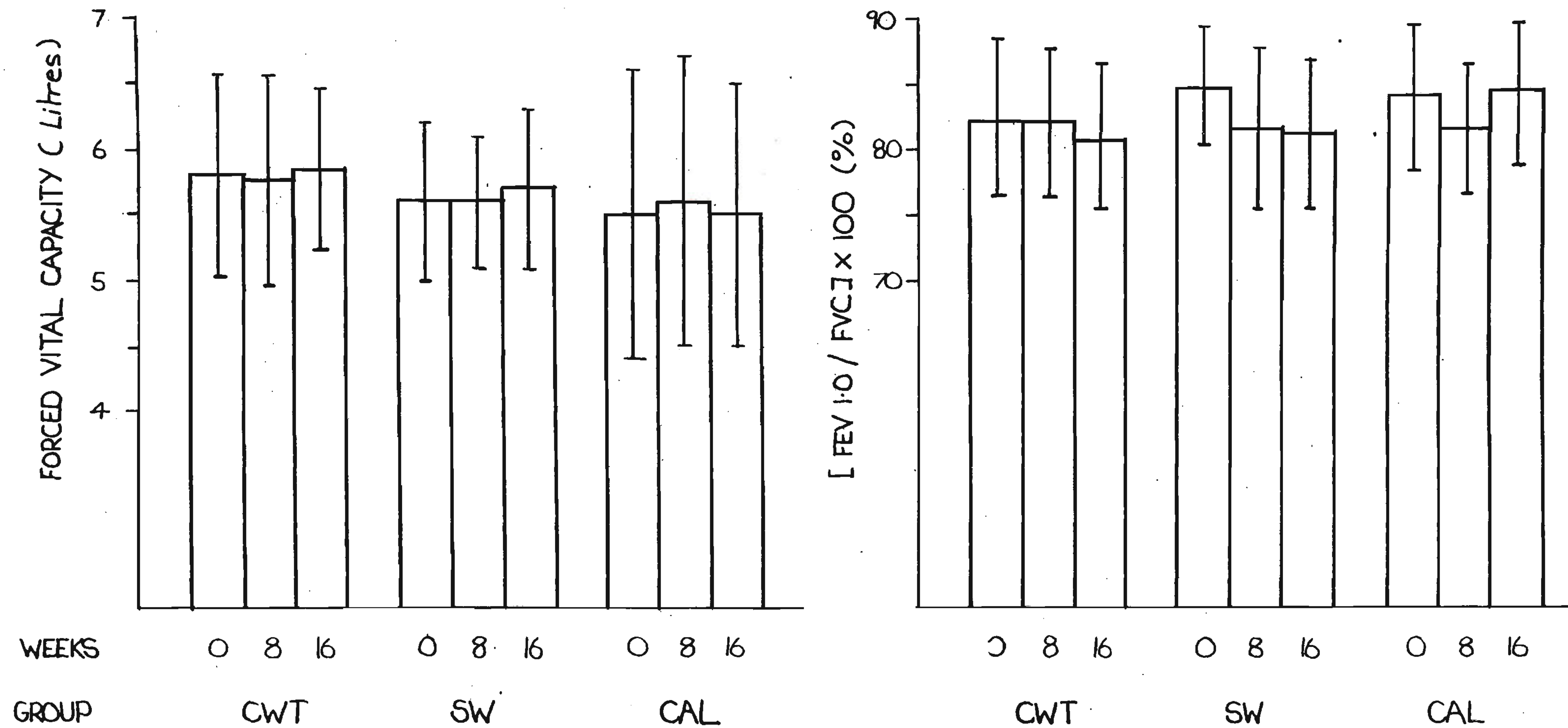
ENDURANCE FITNESS

Physical Work Capacity

Significant differences in physical work capacity were observed both between groups ($F = 3.3$, $p < 0.05$) and across test sessions ($F = 11.2$, $p < 0.05$). However, the difference observed between groups was not supported by the more stringent Scheffé method for comparing all pairs of means, and is therefore unlikely to be of physiological importance (See Figure 15).

Physical work capacity increased significantly in all activity groups over the sixteen week training period (CWT $S = 232.1$, $p < 0.1$: SW $S = 261.8$, $p < 0.1$: CAL $S = 274.6$, $p < 0.1$).

Using frequency of attendance as a covariant between the groups



CWT = Circuit weight training SW = Swimming CAL = Calisthenics / Endurance games
Values shown are means, bars indicate ± 1 Standard deviation

Figure 14: Changes in lung function during sixteen weeks of regular physical activity.

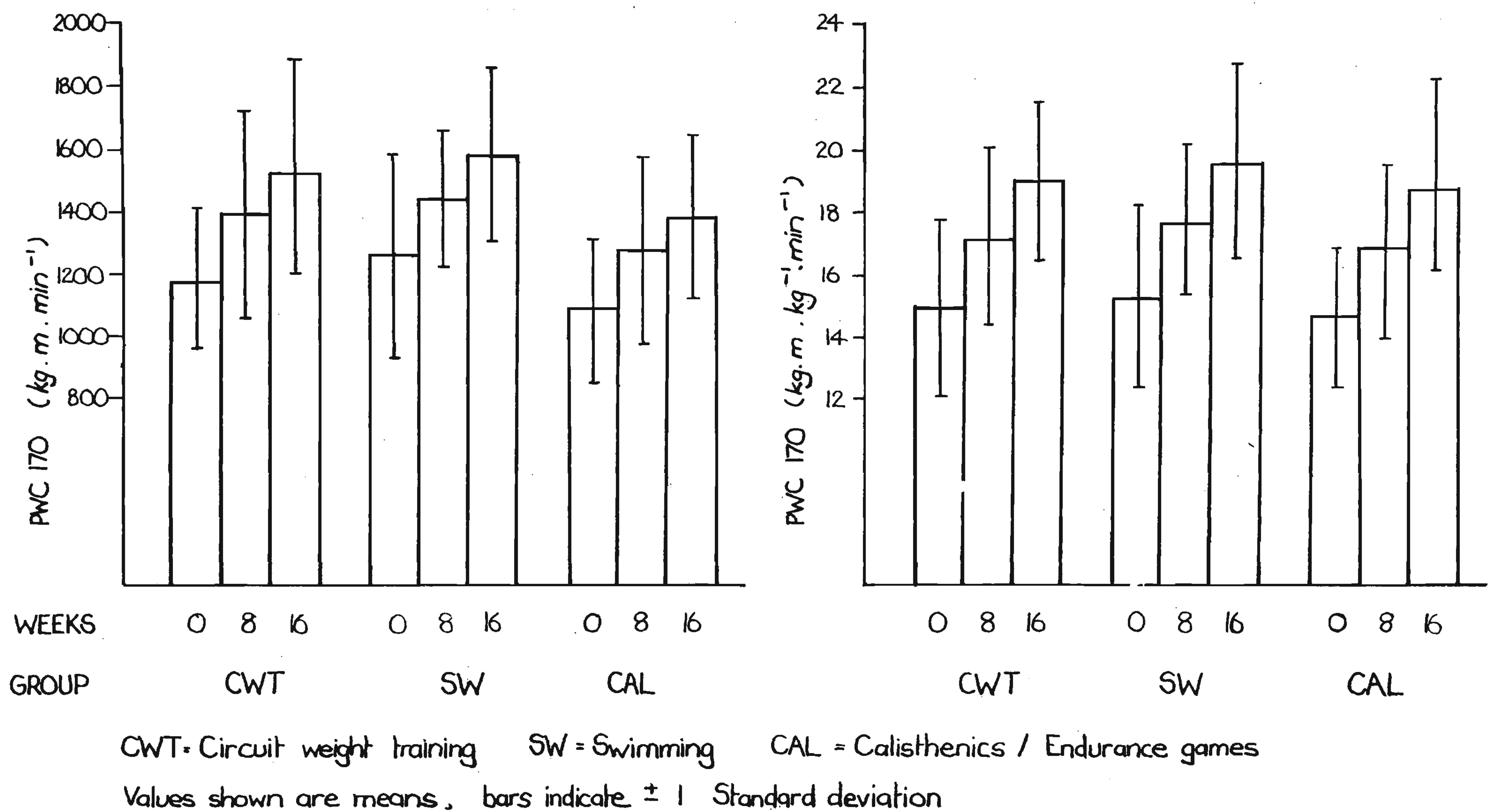


Figure 15: Changes in endurance fitness during sixteen weeks of regular physical activity.

did not significantly affect the changes observed in physical work capacity.

Physical Work Capacity per Kilogram of Body Weight

A significant difference in physical work capacity per kilogram of body weight was observed across the test sessions ($F = 20.2$, $p < 0.05$). Physical work capacity per kilogram of body weight increased in all groups during the sixteen weeks training (CWT $S = 2.3$, $p < 0.1$: SW $S = 2.5$, $p < 0.1$: CAL $S = 2.7$. $p < 0.1$). No significant difference was observed between the groups (See Figure 15).

Using frequency of attendance as a covariant between groups did not significantly affect the changes in physical work capacity per kilogram of body weight.

The increase in physical work capacity observed with regular physical activity, both in absolute terms and per kilogram of body weight, is consistent with observations made by previous investigators (7, 10, 30, 33, 35, 36, 38, 40, 44, 50, 51, 53, 60, 61, 62, 64, 65, 66, 67, 68, 75, 80, 88, 100, 104).

All groups increased in endurance fitness at approximately the same rate throughout the study. Previous research has indicated that circuit weight training and calisthenics programmes produce only a small increase in aerobic power when compared with other activites (29, 30, 60, 99, 102). The results of the present study contradict these previous findings. The combination of endurance games with calisthenics exercises, and the addition of five minutes of aerobic cycling to the circuit weight training programme appear to have enhanced the development of cardio-respiratory fitness in these activities to such an extent that they compare favourably with the increase in physical work capacity observed with swimming.

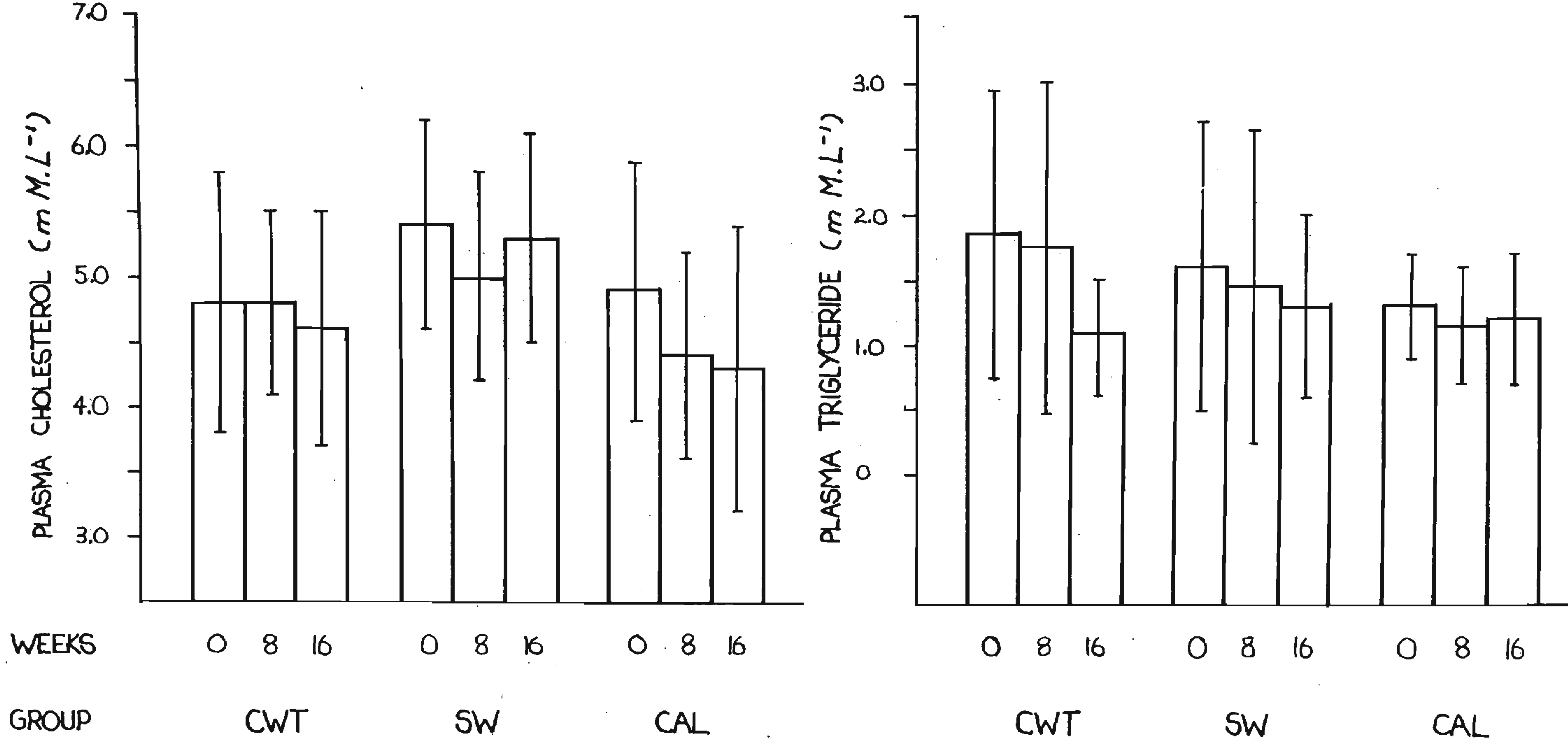
The results of the present study indicate that regular physical activity within the guidelines set by the American College of Sports Medicine (2) will improve endurance fitness, both in absolute terms and in relation to body weight. The increase observed was independent of the mode of activity.

BLOOD ANALYSIS

Cholesterol

No significant change in cholesterol was observed across test sessions during the sixteen week period of training. However a significant difference was observed between the groups ($F = 5.3$, $p < 0.05$). After sixteen weeks of regular activity the swimming group had a significantly higher level of cholesterol ($S = 0.96$, $p < 0.1$) than the other groups (See Figure 16). The differences between groups are not physiologically critical as all were within the normal range of values (5.72 to 6.24 $mM.L^{-1}$ or less).

Previous research has shown conflicting results concerning the effect of exercise on cholesterol levels. The findings of the present study where dietary fat intake did not alter, are in accordance with those that have found no change in cholesterol levels with training (10, 16, 38, 47, 54, 63), and contrary to those investigations which have shown cholesterol levels to decrease with physical training (15, 25, 28, 34, 37, 46, 49, 50, 71, 89). This suggests that in order to reduce cholesterol levels there is a need for appropriate dietary modification in conjunction with exercise. This is supported by Montoye et al. (54) who suggest that the effects of exercise on serum cholesterol levels are indirect.



CWT = Circuit weight training SW = Swimming CAL = Calisthenics / Endurance games

Values shown are means, bars indicate $\pm$ 1 Standard deviation

Figure 16: Changes in plasma cholesterol and triglyceride during sixteen weeks of regular physical activity.

Triglycerides

No significant differences were observed in triglycerides, either between groups or across test sessions during the sixteen week training period (See Figure 16).

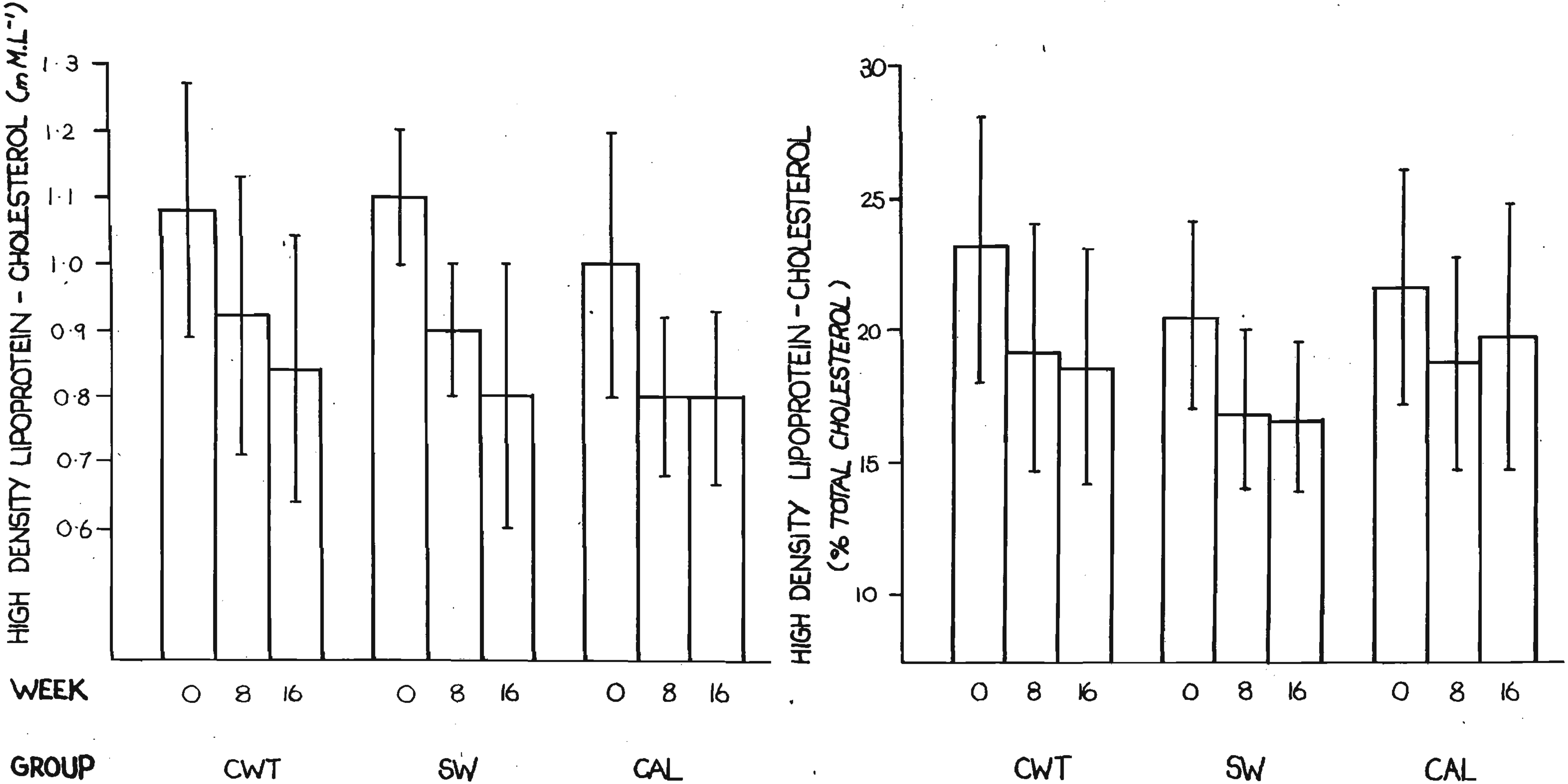
This result is incompatible with findings of previous investigations, which have shown that endurance training decreases the level of serum triglycerides in subjects with both normal and elevated triglyceride levels (10, 16, 28, 37, 38, 40, 63).

In order to decrease the triglyceride level and maintain this reduction, the physical activity needed to be at a sufficient level to produce a cardiovascular training effect, and continued regularly (10, 71, 89). In the present study the different activities were performed at a sufficient level to produce a training effect, as measured by increased physical work capacity. Most previous investigations have neither controlled nor monitored the diet of their subjects. Dietary monitoring, in the present study, has indicated that total dietary fat intake did not change within the duration of the training period. This suggests that exercise alone may not be sufficient to favourably modify serum triglyceride levels.

High Density Lipoprotein Cholesterol

A significant change in high density lipoprotein levels was observed across the test sessions ($F = 19.5$, $p < 0.05$). No significant difference was observed between the groups, with all groups having values within the normal range (0.7 to 1.9 $mM.L^{-1}$) (See Figure 17).

High density lipoprotein reduced significantly in all groups over the sixteen week training period. (CWT $S = 0.14$, $p < 0.1$: SW $S = 0.16$, $p < 0.1$: CAL $S = 0.16$, $p < 0.1$). The major portion



CWT = Circuit weight training SW = Swimming CAL = Calisthenics / Endurance games

Values shown are means, bars indicate ± 1 Standard deviation

Figure 17: Changes in high density lipoprotein cholesterol during sixteen weeks of regular physical activity.

of this change occurred in the first eight weeks of the programme (CWT $S = 0.15$, $p < 0.1$: SW $S = 0.16$, $p < 0.1$: CAL $S = 0.16$, $p < 0.1$).

The results of the present study are at variance with observations of previous investigators, who found that high density lipoprotein levels increased significantly with physical training, and that this increase was highly associated with the total amount of training done per week (40, 47, 97).

The findings of the present study indicate that exercise alone may not be sufficient to favourably modify high density lipoprotein levels.

High Density Lipoprotein - Cholesterol as a percentage of Total Cholesterol

A significant difference in high density lipoprotein-cholesterol as a percentage of total cholesterol was observed across the test sessions ($F = 8.2$, $p < 0.05$) with no significant differences between the groups. The percentage of total cholesterol attributed to high density lipoprotein decreased significantly during the sixteen week training period in the circuit weight training group only ($S = 3.5$, $p < 0.1$). A greater proportion of this change occurred in the first eight weeks of the programme ($S = 3.6$, $p < 0.1$) (See Figure 17).

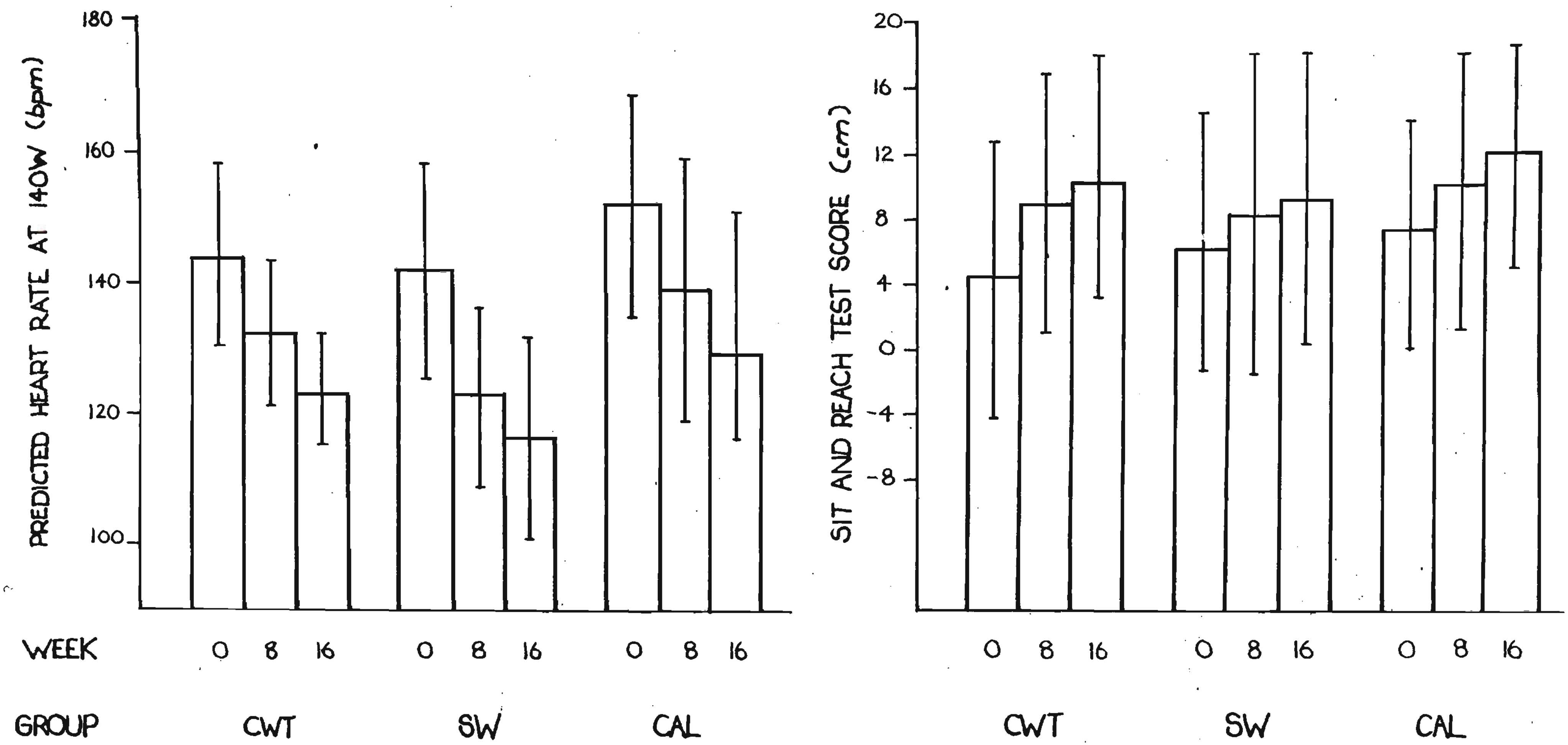
It would appear that no previous investigators have considered the effects of exercise on this parameter. The changes observed in the present study reflect the decrease in high density lipoprotein levels while the cholesterol levels did not change. This change is opposite to that expected and is probably related to the fact that dietary fat intake remained unchanged throughout the study.

It would appear that exercise alone does not positively modify the levels of blood fats and lipoprotein. To significantly change the level of these variables in the blood, dietary modifications may be required with particular reference to the total energy intake, and the percentage of the total energy intake derived from fat.

Physical activity of low to moderate intensity has been shown not to affect the levels of the blood fats (71, 89). It may be possible that the exercise in this study, although sufficient to produce a cardio-respiratory training response, did not have the correct combination of duration, intensity or frequency to favourably modify the level of blood fats or lipoproteins.

FLEXIBILITY

No significant differences in flexibility of the lower back and posterior thigh were observed either between groups or across the test sessions during the sixteen week training period. Although the flexibility of each group increased over the training period, this increase was not large enough to achieve statistical significance. This may have been due to the large range of individual scores as indicated by the high standard deviation of values (See Figure 18).



CWT=Circuit weight training SW= Swimming CAL = Calisthenics / Endurance games
Values shown are means, bars indicate ± 1 Standard deviation.

Figure 18: Changes in heart rate during submaximal work, and lower back/thigh flexibility during sixteen weeks of regular physical activity.

PREDICTED HEART RATE AT 140 WATTS

Significant differences were observed in predicted heart rate both between groups ($F = 6.4$, $p < 0.05$) and across test sessions ($F = 23.2$, $p < 0.05$) during the training period (See Figure 18). At the commencement of training there were no significant differences between the groups, but following eight weeks of training the swimming group had significantly lower heart rates at 140 watts than the calisthenics group ($S = 13.8$, $p < 0.1$). The calisthenics group was the only activity group not to have a significant reduction in heart rate during the first eight weeks of the programme (CWT $S = 12.4$, $p < 0.1$; SW $S = 13.4$, $p < 0.1$).

Heart rate at 140 watts reduced significantly in all activity groups over the sixteen week training period (CWT $S = 11.6$, $p < 0.1$; SW $S = 13.4$, $p < 0.1$; CAL $S = 13.7$, $p < 0.1$). After sixteen weeks of regular activity, the difference in heart rate between the swimming and calisthenics groups had disappeared. The consideration of differences in frequency of attendance at training sessions as a covariant between the groups, did not explain the greater decrease in heart rate at 140 watts that occurred in the swimming group during the first eight weeks.

These results are in agreement with observations of previous investigators, that heart rate during submaximal exercise decreases with training, indicating more efficient oxygen transport with less strain on the cardiovascular system and functional reserve (1, 7, 24, 31, 35, 36, 43, 46, 60, 66, 76, 79, 80, 81, 95, 96, 100). This reduction in the heart rate at submaximal workloads corresponds to a significant increase in physical work capacity at a heart rate of 170 beats per minute ($kg.m.min^{-1}$), which also reflects the general power of the circulatory system.

CHAPTER 4

SUMMARY AND CONCLUSIONS

SUMMARY

The purpose of this study was to evaluate the comparative benefits of four different physical activities on anthropometric, physiological and biochemical parameters, important in health related fitness.

Sixty-five males aged twenty-seven to forty-eight years, who were previously sedentary volunteered to participate in this study. Initially the subjects were randomly allocated to one of the four activity groups (jogging, circuit weight training, swimming and calisthenics/endurance games). Due to a high dropout rate, resulting in insufficient numbers for statistical analysis, the jogging group was eliminated from statistical evaluation. At the conclusion of the study, thirty-five of the original subjects remained in the three activity groups - circuit weight training (n = 14); swimming (n = 11) and calisthenics/endurance games (n = 10).

The subjects trained for sixteen weeks, three to five times per week for fifteen to sixty minutes per session, at an intensity that maintained their heart rate within sixty to ninety percent of their maximal heart rate reserve added to their resting heart rate. A full functional fitness assessment of each subject was carried out by trained testers before, after eight weeks and following sixteen weeks of regular physical activity. All test sessions were conducted in the Exercise Physiology Laboratory at the Physical Education, Health and Recreation Studies Department within the Ballarat College of Advanced Education.

It was found that subjects who trained at the required levels of intensity, duration and frequency as set by the American College of Sports Medicine, showed a significant decrease in systolic and diastolic blood pressure at rest, and in predicted heart rate at submaximal work loads. They also increased their physical work capacity significantly, both in absolute terms and per kilogram of body weight. These changes reflect a more efficient oxygen transport system, with less strain on the cardiovascular system and functional reserve at rest and during submaximal exercise.

Body weight, skinfold thickness, percent body fat, and serum cholesterol and triglyceride levels did not change significantly during the sixteen week training period. Dietary monitoring indicated that neither the total energy intake nor the proportion of energy derived from fat altered during the programme. This indicates that exercise alone may not be sufficient to reduce these parameters significantly, and implies that a modification in diet may be required in conjunction with exercise.

The levels of high density lipoprotein-cholesterol and high density lipoprotein-cholesterol as a percentage of total cholesterol, significantly reduced during the training period. This change was opposite to that expected.

Flexibility of the lower back and posterior thigh, as measured by the 'sit and reach test', was not significantly increased by sixteen weeks of regular physical activity. This may have been due to the large range of initial scores in this test.

CONCLUSIONS

On the basis of these findings, it can be concluded that regular physical activity within the guidelines of the American College of Sports Medicine (2) will elicit an increase in cardiorespiratory fitness and a decrease in resting blood pressure. These changes in cardiovascular function appear to be independent of the mode of activity.

The results of this study indicate that while improving endurance fitness, the level of exercise encountered in the present study does not appear to affect body weight and composition or the levels of lipids in the blood. It must therefore be concluded that some other factor in conjunction with exercise is necessary to favourably modify these parameters. This factor seems most likely to be a decrease in total energy intake and/or a reduction in the proportion of the energy intake derived from fat.

RECOMMENDATIONS

It is recommended that future studies evaluating the effects of exercise on anthropometric, physiological or biochemical parameters should take into account energy intake. The present study has indicated the need to use diet as an independent variable when analysing the effects of exercise on certain physiological parameters.

Further to dietary monitoring, it is recommended that determination of caloric energy expenditure for each activity may be of use in order to equate the caloric expenditure of each group, and to ensure that the minimum required energy expenditure of

1255.8 KJ per session, as set by the American College of Sports Medicine (2), is met.

Replication of this study, with a different age group or with women, would be advantageous in furthering knowledge within the field.

Further studies should make use of different testing procedures, such as maximum oxygen uptake testing, densiometry, and a variety of flexibility and strength tests, in order to compare results.

Further study relating to the effects of exercise on blood lipids is required. Analysis of the effects of different intensity activities in relation to dietary intake would advance knowledge in this area.

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APPENDIX A

BALLARAT COLLEGE of ADVANCED EDUCATION
Gear Avenue
Mount Helen
Victoria 3350
Australia
053 301800

DEPARTMENT OF PHYSICAL EDUCATION, HEALTH AND RECREATION STUDIES.

APPLICATION TO JOIN A PHYSICAL ACTIVITY PROGRAMME

I, ____ (full name)
(please print)

of ____ (address)

____

being over eighteen years of age, do hereby apply to be a subject in the research project entitled "Physiological Responses of Adult Males to Regular Exercise". The consequences and risks involved in my participating as a subject in this project have been explained to me and I understand them fully, and I unreservedly accept responsibility in respect thereof. I agree not to make any claim arising out of my participation in the programme, against the Ballarat College of Advanced Education, or its servants or agents.

I am willing to participate in any of the activity programmes offered.

With respect to the activity of swimming I am able to swim fifty metres.

Yes [ ] No [ ]

Signature: ______________________ Date: ______________

Witnessed by: ________________________________ (Signature)

________________________________ (Full Name)

BALLARAT COLLEGE of ADVANCED EDUCATION
Gear Avenue
Mount Helen
Victoria 3350
Australia
053 301800

DEPARTMENT OF PHYSICAL EDUCATION, HEALTH & RECREATION STUDIES.

Dear Doctor

1) A patient of yours, ______________________, has volunteered to participate in a physical activity programme at the Department of Physical Education, Health and Recreation Studies.

2) As part of this programme there will be a series of physical fitness tests. Your patients responses will be monitored closely throughout the tests. The tests will consist of:

a) Height
b) Weight
c) Blood Pressure
d) Body Fat (Body Composition)
e) Lung Function
f) Endurance Fitness
g) Blood biochemical analysis.

3) Your patient will then participate in an activity programme (one of jogging, swimming, circuit weight training or calisthenics) 3 to 5 times per week for 16 weeks. All activity sessions will be supervised by trained exercise leaders. Your patient could participate in any one of these activities except in the case of non-swimmers or where a specific limiting disability is identified, in which case the subject will be placed in one of the other activities.

I would appreciate your approval and medical clearance to proceed with this testing and activity programme prior to your patients initial appointment on ________________.

If you wish I will be happy to provide you with details of the physical fitness test results of your patient.

Thank you for your assistance in this matter.

Brian Hopley
Postgraduate Student

Alan Roberts, Ph.D.
Senior Lecturer.

I certify that the above patient is able to take part in a testing and physical fitness programme.

Comments: ____

____

____

____

I would like to see results of the testing programme.

Yes ☐ No ☐

Signed ______________________

PHYSICAL CHARACTERISTICS OF SUBJECTS

SWIMMING

Subject	Age	Weight (kg)	Height (cm)
1	30	80.4	175.9
2	35	91.8	180.2
3	31	70.6	174.7
4	30	65.2	169.1
5	43	91.0	181.1
6	48	67.0	171.1
7	45	91.6	185.6
8	45	93.8	183.1
9	35	96.0	180.1
10	38	76.3	175.6
11	32	90.0	180.0

CIRCUIT WEIGHT TRAINING

Subject	Age	Weight (kg)	Height (cm)
1	32	77.6	171.2
2	32	92.7	183.0
3	37	99.8	180.5
4	38	83.0	174.9
5	35	73.0	173.0
6	44	72.4	178.8
7	34	67.4	176.7
8	33	66.8	175.6
9	38	57.0	166.4
10	36	78.6	181.5
11	27	85.1	180.7
12	28	70.6	189.7
13	34	103.6	173.1
14	31	107.3	184.3

CALISTHENICS

Subject	Age	Weight (kg)	Height (cm)
1	29	106.2	182.9
2	32	67.3	166.2
3	45	80.0	175.0
4	31	84.8	184.3
5	44	72.9	180.8
6	34	63.6	163.8
7	31	70.5	168.8
8	31	75.3	187.4
9	37	56.6	164.4
10	31	77.8	181.6